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NUCLEONICS

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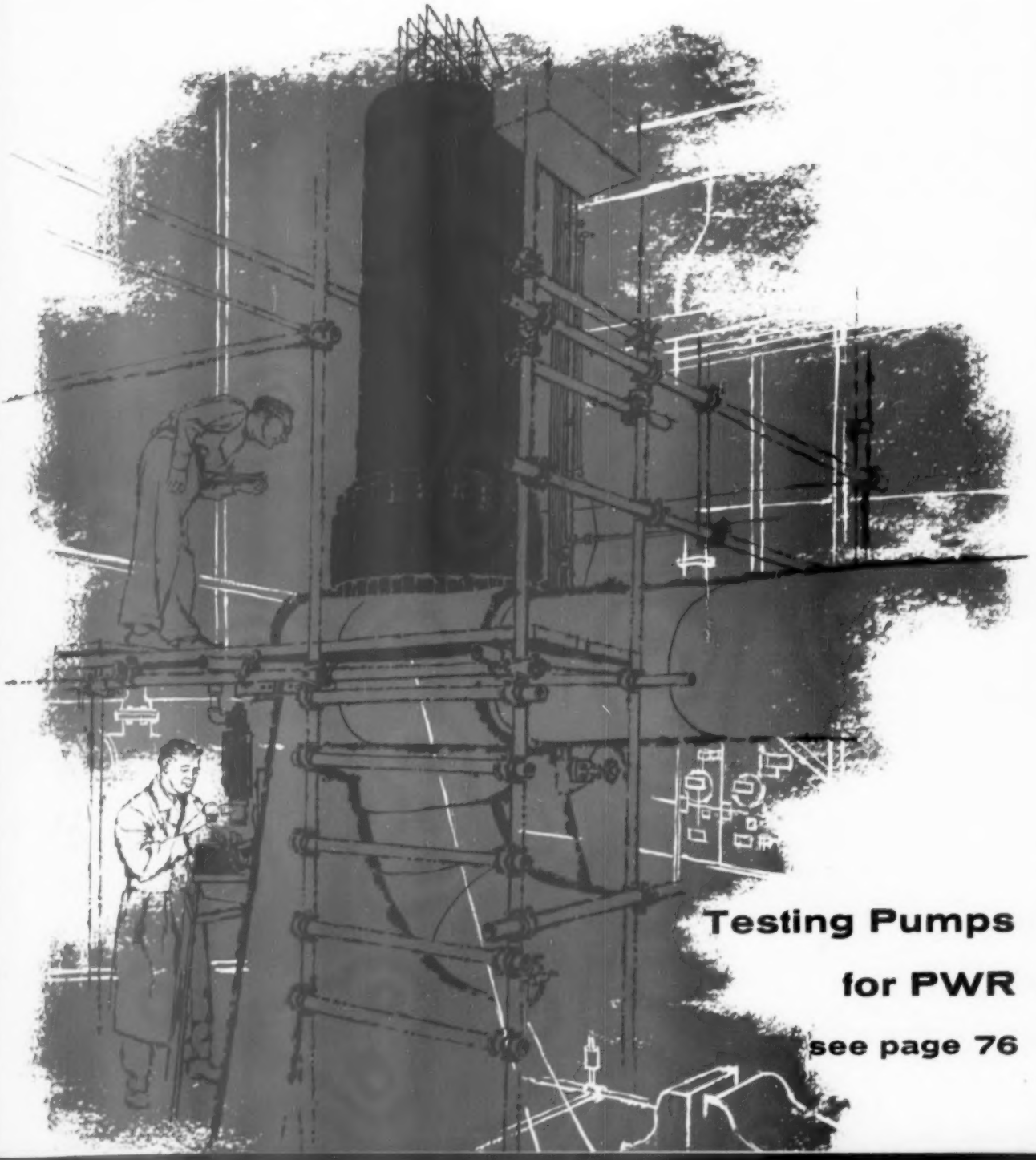

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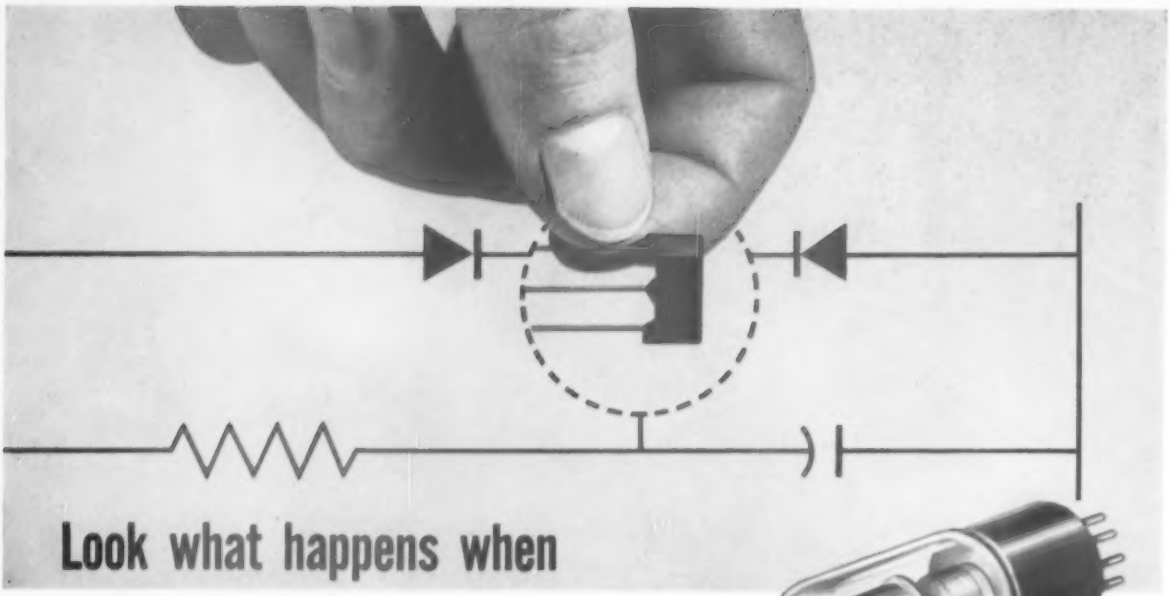

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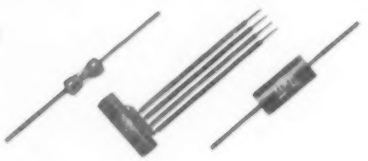

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JULY • 1956

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About NUCLEONICS

One day a couple of months ago, shortly after the President's announcement of the U. S. plan to make 40,000 kg of U^{235} available to foreign countries, the Editors of NUCLEONICS decided that of equal importance to the offer were the ears on which the offer fell. Were they deaf ones, or had they been cocked this way awaiting just such an announcement?

To get answers to these questions, among others, we rushed queries to 15 of our correspondents in countries we felt were most interested in the offer. We instructed our men to contact only policy-level officials who could give meaningful responses. In almost every instance, the cabled answers came as a result of interviews with the top man or men in each nation. Thus, we were able to publish in our April issue an authoritative analysis of world reaction to the Eisenhower offer. The story was important, we felt, because it gave both American officials and American industry a picture of the thinking to anticipate in countries we're anxious to deal with.

We mention this story now not because we want you to go

NUCLEONICS

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NUCLEONICS (with which is consolidated "Atomic Power" and "Atomic Engineering") July, 1956, Vol. 14, No. 7. Published monthly by the McGraw-Hill Publishing Co., Inc., Executive, Editorial, Advertising and Subscription Offices: McGraw-Hill Building, 330 West 42nd Street, N. Y. 36, N. Y. Publication Office, 212 East York St., York, Pa. Entered as second class matter December 17, 1947 in the Post Office at York, Pa., under the act of March 3, 1879. Copyright 1956 by McGraw-Hill Publishing Company, Inc. All rights reserved. Donald C. McGraw, President, Paul Montgomery, Executive Vice President; Joseph A. Gerardi, Vice President and Treasurer; John J. Cooke, Secretary; Nelson Bond, Executive Vice President, Publications Division; Ralph B. Smith, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; J. E. Blackburn, Jr., Vice President and Director of Circulation. **FOR SUBSCRIPTIONS,** write to Nucleonics-Subscription Service, 330 West 42nd Street, New York 36, N. Y. **Orders must indicate company and position.** Allow one month for change of address. Price per copy $.75. Subscription rates: United States and U. S. Possessions $8 for 1 year, $12 for 2 years, $16 for 3 years. Canada $10 for 1 year, $16 for 2 years, $20 for 3 years. Other Western Hemisphere countries and the Philippines $10 for 1 year, $16 for 2 years, $20 for 3 years. All other countries $15 for 1 year, $25 for 2 years, $30 for 3 years. Member of ABC. Member of ABP.

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About NUCLEONICS (Continued)

back and read the article again (although we must confess we've never been modest about suggesting that anyone reread something in NUCLEONICS) but rather because we thought you might be interested in knowing how we assemble news from abroad. Although NUCLEONICS is primarily a technical magazine, we consider our news coverage to be an extremely important part of our service to readers.

And so important, we feel, is our reporting from abroad that last month we added the names of our full-time correspondents in seven countries to the masthead on the contents page. This month, we're adding the names of eight of a few of our more important "stringer" correspondents. Actually, they are only a small part of the total of 61 newsmen reporting for us around the world.

In these days of the international atom, not only is it nice to have eyes and ears (and pencil) in the right place at the right time but it is vital. The next several years will see real advances in policy decisions, research and engineering development, and the building of nuclear facilities in many countries. To keep our readers abreast of these events (and ahead of them, if possible), we're going to use our world news staff as more than just window dressing.

In fact, although, they've really been working hard for us in recent months, we're now putting them on a regular schedule of feeding information to us in New York. As part of an expanded ROUNDUP section, we're adding a "newsletter from abroad." In this way, in addition to our existing "World News" coverage, we'll be presenting a continuing and more complete picture of world activities.

Of course, if we're neglecting some area of foreign coverage that some reader feels we should be hitting, we'd be delighted to hear of this.

•

A word of explanation on something different in this issue—the color photograph on p. 21. This is in the spot normally occupied by the editorial. And it's not there because the editor was too lazy to write an editorial. Rather, this page was chosen because it was the best place to run an isolated photograph, one not tied in with any article, and also it enables us to get blue ink that ties in with a printer's form already containing this color ink.

The picture itself is unusual in that we have to leave it to the reader's imagination to determine its interest and significance in the nuclear field. In fact, we too have to do some guessing. When we spotted the photo at Oak Ridge National Laboratory, it appealed to us first from the photographic point of view. But then all that we could learn about it was that it was "super heavy water" under the conditions shown on p. 21. We were told that this is all that could be declassified.

At ORNL the two projects that are probably the most secret are the lab's work in the aircraft nuclear propulsion field and its contribution to thermonuclear Project Sherwood. Thus, it doesn't seem unreasonable to guess that the photo is connected with one of these projects.

—The Editors

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CVC's model LC1-14 high-vacuum system measures 39" by 30" by 88" with a chamber 14" in diameter, 24" high. It produces a pressure of 0.5 micron Hg in five minutes. High-vacuum valve isolates diffusion pump while chamber is opened to atmosphere.

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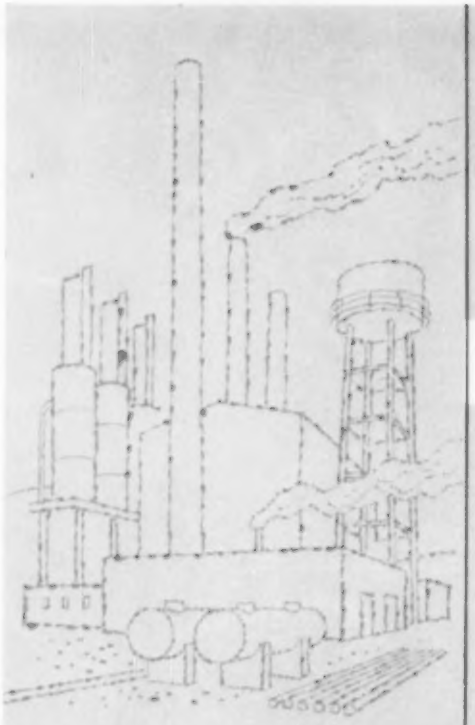

during the past five years,

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today,

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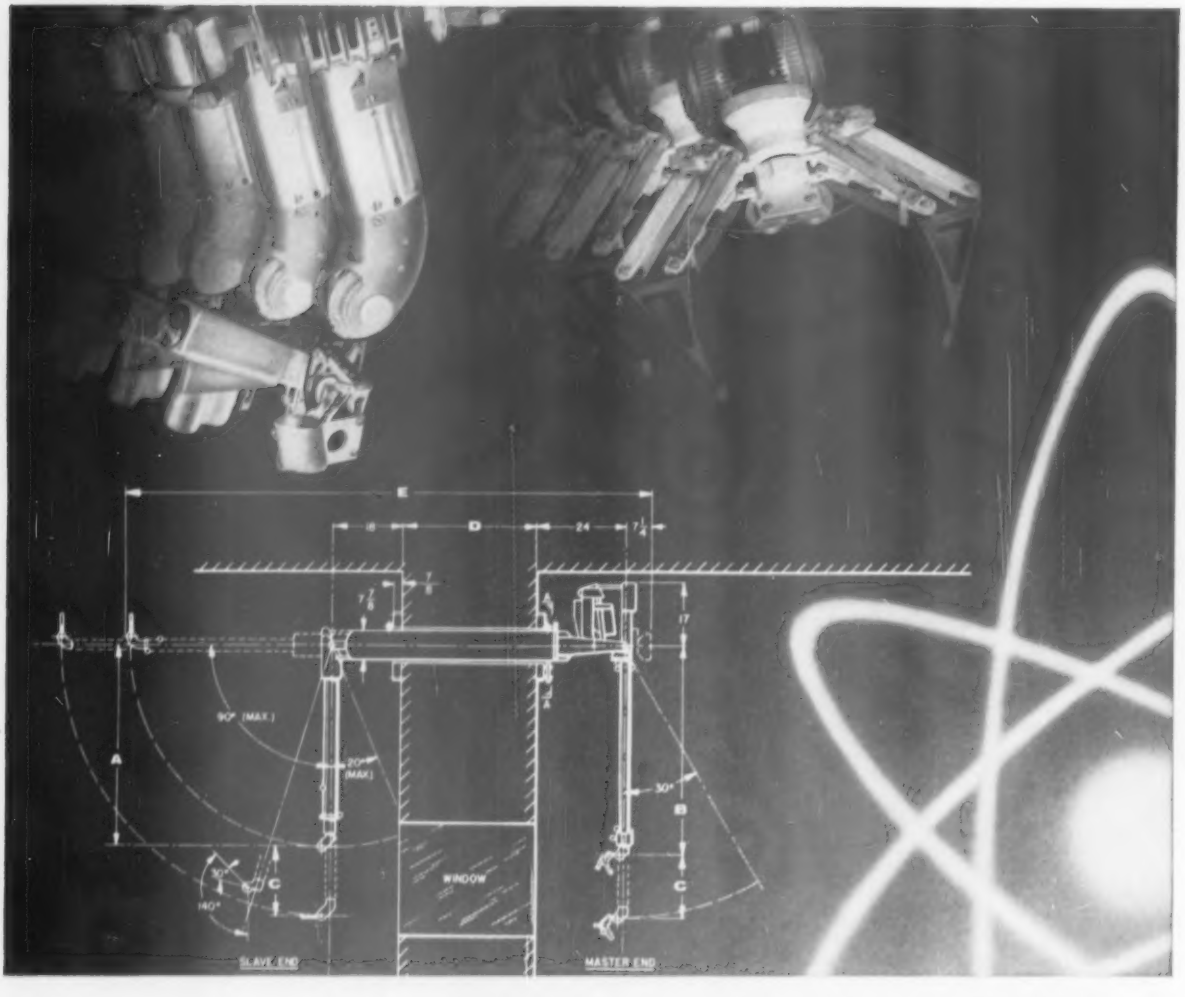
If your future plans include any phase of nuclear application, write **Kaiser Engineers, Nuclear Engineering Division,** Kaiser Building, Oakland 12, California.



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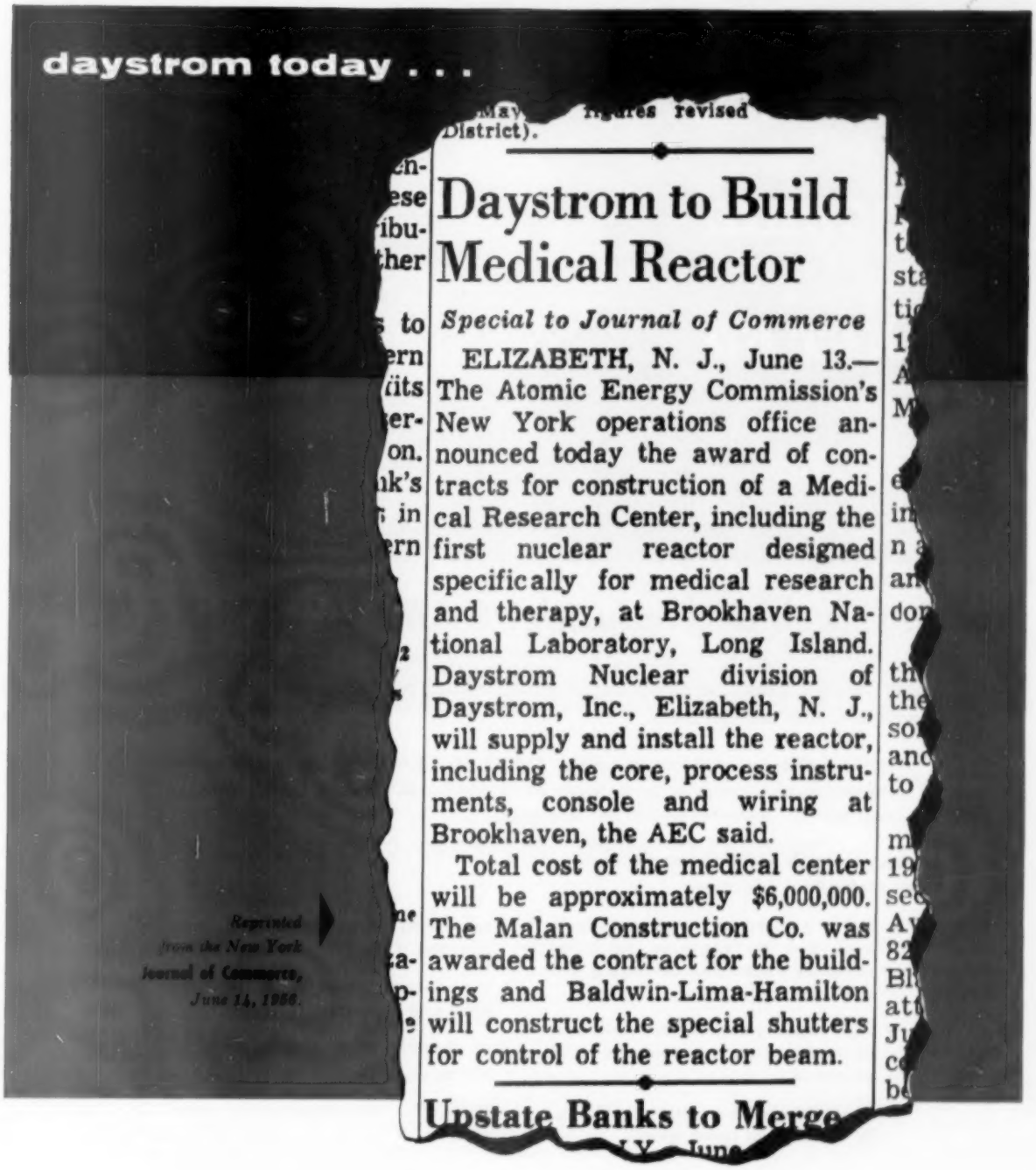

Reprinted from the New York Journal of Commerce, June 14, 1956.

Daystrom to Build Medical Reactor

Special to Journal of Commerce

ELIZABETH, N. J., June 13.—The Atomic Energy Commission's New York operations office announced today the award of contracts for construction of a Medical Research Center, including the first nuclear reactor designed specifically for medical research and therapy, at Brookhaven National Laboratory, Long Island. Daystrom Nuclear division of Daystrom, Inc., Elizabeth, N. J., will supply and install the reactor, including the core, process instruments, console and wiring at Brookhaven, the AEC said.

Total cost of the medical center will be approximately $6,000,000. The Malan Construction Co. was awarded the contract for the buildings and Baldwin-Lima-Hamilton will construct the special shutters for control of the reactor beam.

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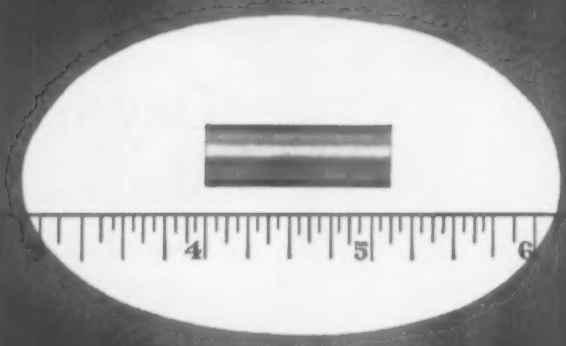

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Advertisers who are exhibiting announce booth numbers and preview the products they'll show at the Trade Fair. Advertisers not exhibiting get attention from NUCLEONICS readers who pore over the pages of the pre-show issue before the rush and crowds of show-time. And as a special feature NUCLEONICS will have a preview-in-print of the Trade Fair with capsule descriptions of each exhibit in the show.

15,000 key people from industry, government and science (twice last year's attendance) are expected to view 240 booths at Navy Pier. At the same time a forum meeting on "Management and Technology for the Atomic Market" will be held at the Morrison Hotel in Chicago.

The pre-show NUCLEONICS will be in the mail on September 8th . . . well ahead of show-time. Reserve space now for this important issue. Closing dates: Copy to set—July 25th; Complete plates—August 8th.

a special **NUCLEONICS** article on **radiation effects** will give this issue even greater value . . .

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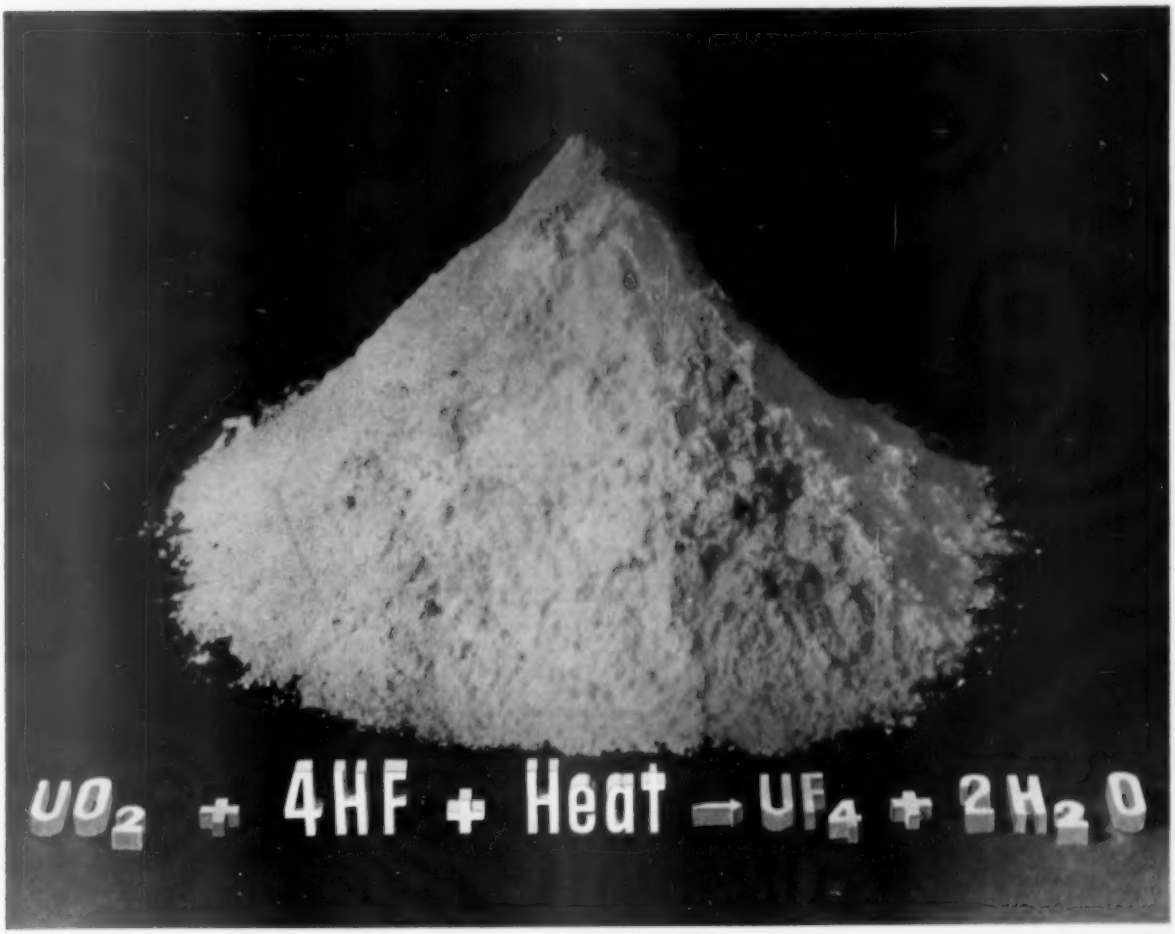

Two reasons why they make "green salt" in Inconel furnaces

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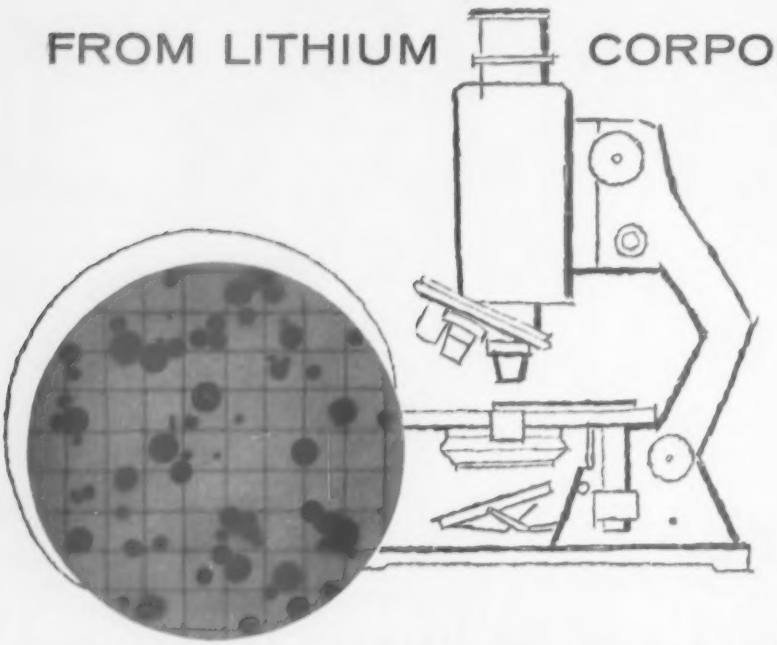

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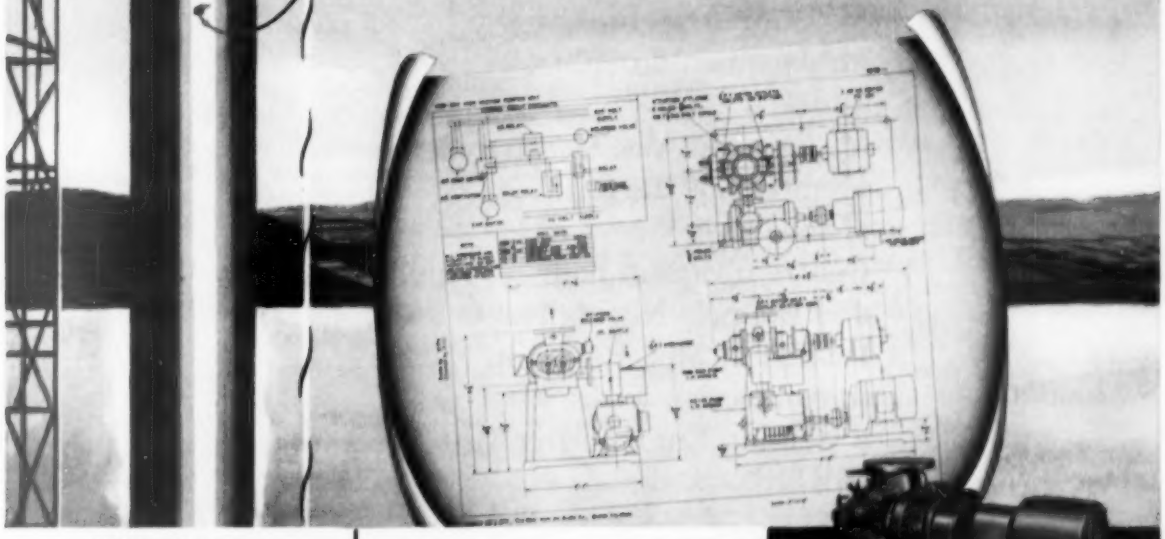
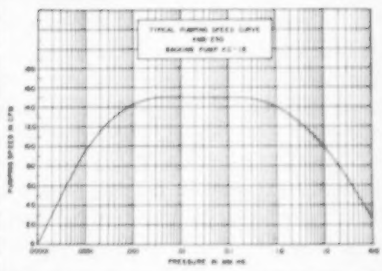


SPECIFICATION DATA
Model KMB-230 Two Stage Mechanical Booster Vacuum Pump

Ultimate Pressure (McLeod Gauge)	0.1 Micron
Free Air Displacement	230 CFM
RPM	3600/540
Motor H.P.	2 and 1
Oil Capacity	5 Pints
Cooling	Water
Shaft Seal	Mechanical
Shaft Diameter	3/4-3/4
Inlet Connection	4" Flanged
Outlet Connection	1¼" Screwed
Net Weight, Complete	1010 lbs.



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ROUNDUP of Key Developments in Atomic Energy

LATE NEWS and Commentary

International Scene

Fast and furious were developments along the international atoms-for-peace front last month. Some were encouraging—like the new bilaterals laid before Congress, reactor sales abroad, and liberalization of U. S. rules on supplying enriched uranium; others appeared setbacks, such as developments in Belgium and Japan.

Lying before Congress for the required 30-day waiting period were 17 bilateral accords. These include 7 research pacts—two previously-announced ones with West Germany and Ireland, and new ones with Austria, Costa Rica, Cuba, Dominican Republic, and New Zealand; three new 10-year power bilaterals with Australia, Netherlands and Switzerland, each providing for sale of up to 500 kg of contained U^{235}; one in-between arrangement with France that an AEC official describes as "either an elaborate research bilateral or an unclassified-data power bilateral—we think it is rather the latter": it provides 40 kg enriched U to be used either in a power or experimental-power reactor, and—like the three other power pacts—permits export of 90%-enriched U for use in materials-testing reactors. Finally, there are six amendments to existing bilaterals with Belgium, Britain, Canada, Denmark, Germany and Sweden; the first three concern power pacts and broaden the whole area of exchange of information; the last three, amending research bilaterals, increase the amount of 20% U^{235} available from 6 to 12 kg. Pending, and with the next move up to the foreign country, are power bilaterals with Brazil, India, Italy, Japan, and Norway.

Reactor Sales

Four research reactors were sold by U. S. firms to countries with bilaterals (plus a power reactor to a country not yet so empowered: *see p. R10*). These five brought total U. S. sales abroad by private firms to ten (NU, April '56, p. 17). AEC said it expected more than 20 sales by the end of 1957. Denmark and the Netherlands followed Spain and Brazil (NU, June '56, p. 22) in getting U. S. contributions of $350,000 each toward their research reactors. Denmark bought a 5-Mw tank-type unit similar to the Livermore research reactor from Foster Wheeler Corp. for delivery in about a year. It will use 28.5 Kg of 20%-enriched U, and will cost $578,000–867,000; it will be located at the $1.4-million Danish nuclear research center at Risø near Copenhagen. The Dutch turned to ACF Industries Inc. for a $2-million modified pool-type reactor similar to the Oak Ridge research reactor now building; this high-flux experimental tool will take 3 years for completion at the $3-million Netherlands Reactor Center. West Germany bought two swimming pools: one costing $450,000 from AMF Atomics for the Technical University at Munich, for nuclear training purposes; the other from Babcock & Wilcox for ship-propulsion research at Hamburg. The 1-Mw Munich pile will be the first university reactor installed in free Europe for teaching nuclear science. (The Germans also bought in Britain a MERLIN—Medium Energy Light-water-moderated Industrial Nuclear Reactor, a 5-Mw (heat) swimming-pool using 30 kg of 20%-enriched uranium oxide, from Associated Electrical Industries, London, for $200,000; AEI is building another Merlin for its own research center (NU, March '56, p. 23). Germany plans to buy a second British reactor, a larger, Dido-type 10-Mw materials-testing unit costing $6-million, from Head, Wrightson & Co. Ltd. Both are destined for a research center at Königsforst near Cologne, the Merlin to be delivered in a year, the Dido in 2–3.)

U. S. Policy Changes

Two liberalizations of U. S. nuclear policy, quietly made by AEC, may be expected to have a resounding effect in furthering the atoms-for-peace program. The bugaboo of required return for reprocessing of U. S.-supplied enriched uranium (NU, March '56, p. 17, April p. 19 ff), which prestige-conscious countries objected to as a sign of lack of confidence, was eliminated. The new power bilaterals provide for reprocessing either in the U. S. or at an approved facility abroad if that should be desirable for technical, economic (e.g. transportation

cost), or fuel-accountability reasons. Secondly, a new policy permits export of 90%-enriched uranium for use in materials-testing reactors (which are exceedingly difficult and uneconomic to try to make work with 20% U). Until recently, tight-security advocates in AEC would have considered even the suggestion of exporting 90%-enriched U shocking.

Darker Side

Not all was unrelieved brightness, however. Clouds were supplied by a minor setback in Belgium, and a disquieting development in Japan (*see p. R5*). In Brussels, NUCLEONICS learned that the site for the Westinghouse 11.5-Mw power reactor (NU, Dec. '55, p. 11), and the plans to have it provide power and an added spectacle for the 1958 World's Fair, have been abandoned. A new site presumably will be sought as the reactor is now expected to go critical about the end of 1958—after the Fair's close. Real reason for scrapping the site was fear of possible radiation effects on the Belgian royal family: the site was opposite the curving walls of the gardens of Laeken Palace, the royal residence. Objections in the Brussels City Council, attributed to "La Liste Civile" (meaning the administration of the Royal Household), were promptly hushed up by presiding Burgomaster Cooremans; but *La Libre Belgique*, most royalist of Brussels dailies, made no bones about the source of the objections. A number of 40-ft steel pilings already sunk into the ground for foundations have been pulled up again. Lack of an alternate site makes it impossible to meet an already-tight schedule for completion by Fair opening.

•

More on Gore Bill

A modified, broadened version of the Gore bill (NU, June '56, p. 17) was approved by the Joint Committee on Atomic Energy by 14–0, squeaked by the Senate 49–40, and was to come up on the House floor as this went to press. Senator Gore told NUCLEONICS he was "very pleased" with the bill in its revised form. The controversial measure, aimed at accelerating the civilian atomic power program "at the maximum possible rate consistent with the status of the development of the art," is now three-pronged: it calls for 1. building an unspecified number (instead of six) of "large-scale prototype power reactor demonstration facilities . . . for the generation of electric energy in industrial or commercial quantities," at sites of major production facilities operated by or for AEC, the power to be used by AEC (this latter provision is intended to remove the bill from the private vs. public power controversy); 2. developing and, as soon as practicable, building promising advanced types of reactors in the 10–50-Mw range; 3. conducting "a vigorous program of international cooperation and assistance in the design, construction, and operation of power reactors and related matters." The bill authorizes expenditure of $400-million for the accelerated program. All reactor construction under its provisions is to be carried out under contract with private concerns. Commenting on this feature, JCAE chairman Anderson declared, "This bill will broaden the base of private industrial participation in the atomic power program and will offer a great opportunity to those firms not presently participating in the program to contribute their efforts and talents." (Earlier, he had carried out a survey of 42 firms not including GE, Westinghouse, B&W, NAA, Combustion Engineering, AMF, NDA: 39 replied, of whom 18 said they were qualified and willing to assume full responsibility as prime contractor on a reactor job; 9 were ready to accept partial—i.e. non-nuclear—responsibility; 10 were willing to take on prime contractorship but indicated they would subcontract the nuclear work—which would do nothing to improve the manpower bottleneck; and two said no.

Senate Republicans, and the GOP leadership in AEC (opposed by Democratic Commissioner Murray) are fighting the bill on the ground it does nothing AEC is not already empowered to do and in fact doing. Democrats insist the shot in the arm is needed.

AEC reactor chief Davis said he felt the only type "deserving" development now is a D_2O-moderated and -cooled tube-type reactor (similar to Canada's NPD); earlier, his experts mentioned gas-cooled, pressurized Savannah-River-type, and graphite-moderated with pressurized D_2O coolant tube, as likely possibilities.

Nuclear Industry Takes Report on Radiation Effects In Stride; Pessimism on Heredity Peril Felt Unjustified

Much more measured and sober, much less alarmed, was the reaction of people in the nuclear energy industry to the six summary reports on the biological effects of nuclear radiation—advance condensations of a massive job carried out by the National Academy of Sciences under a Rockefeller Foundation grant—than had been the reaction of the daily press and general news-magazines. Where the latter had cast a definite pall of apprehension or fear over the prospect that peaceful development of nuclear energy might prove a peril to the future of mankind, informed opinion was rather that the report merely documented what was already largely known about a situation looming on the horizon that required advance planning but for which there was adequate time to plan.

The reports will not affect the nucleonics industry seriously, because it had already been working at maximum-permissible-exposure levels considerably below those recommended. The nuclear industry has been so conservative right from the start, according to a distinguished expert in the field, Lauriston S. Taylor, that their average exposure of their personnel is of the order of one-fifth of present permissible levels. Taylor, chief of the atomic and radiation physics division of the National Bureau of Standards and chairman of the National Committee on Radiation Protection, was not among the 147 scientists who spent a year preparing the studies.

However, he pointed out, the people more likely to feel the pinch are other industries that have long been using X-rays for commercial testing of castings, etc. In this field —much larger than medical radiology—the tendency naturally has been to install a minimum of shielding; this industry may find itself having to add enough shielding to cut incident radiation to one-fourth (for a 24-in. concrete wall this means adding 5–6 in.). Cost factors are negligible for a new installation, but can be quite heavy for altering an existing one.

The six reports are on genetics, pathology, meteorology, oceanography and fisheries, agriculture and food supplies, and disposal of radioactive wastes. None of them except the genetics report contains any numbers. They make no specific, only general recommendations: they are intended primarily as a statement of the problem, of where things stand. They contain nothing that the National Committee on Radiation Protection was not already aware of, nothing that will require any major changes in maximum-permissible-exposure levels. AEC is not expected to take any action pursuant to the Academy reports.

Far from justifying the pessimism they aroused in the popular press, the reports should be a help rather than a hindrance. This is the view, among others, of Columbia Univ. physicist Gioacchino Failla, chairman of the AEC Advisory Committee on Biology and Medicine, who explains, "Until we got a statement from the geneticists, some could always shout that any maximum was too much; but now that the geneticists have named figures, it's something we can live with, for quite a few years to come."

The figures the geneticists named were a basic 0.3 roentgen/wk maximum dose to the gonads for individuals, plus additional maximums of 50 rem (roentgen-equivalent/man) cumulative to age 30, another 50 rem to age 40, and another 100 rem to age 60. These are for external radiations; for internal emitters (radioisotopes in the body) these figures should be reduced by a factor of three.

The 0.3 rem/wk maximum is for occupational exposure, and is the same figure as that recommended by the NCRP and set by AEC for its installations and contractors. In actual practice, exposure on AEC jobs is much less. Annually, 0.3 rem/wk works out to 15.6 rem; thus if an industry wants to expose personnel continuously, it would have to cut down existing maximums by a factor of three to stay within the Academy recommendation of 5 rem/yr maximum occupational exposure. As a matter of actual practice, however, 3 rem/yr is exceeded in only 0.2% of cases of individual exposure in the nuclear industry.

The 50 rem total to age 30 is for nonoccupational groups—the general population—and represents a maximum weekly dose one-tenth that for occupational groups. NCRP has already recommended a much lower maximum of 15–18 rem total to age 30 for the general population, while permitting 150

Highlights from Reports' Recommendations

These are among the significant recommendations of the National Academy of Sciences radiation reports, other than those mentioned in the adjoining article:

- Until advances in reactor technology substantially reduce potential hazards, buildings that house reactors located near populated areas should be sealed against the release of radioactive materials in the event of accident.

- Research should be accelerated, particularly on safety devices for control of accidental power surges in reactors; selection of biologically suitable sites for various nuclear facilities; geophysical and geochemical aspects of ultimate disposal of radioactive wastes; mixing between various parts of the oceans and of the atmosphere.

- A national agency should control and keep records of all dumping of radioactive material in the ocean. An international body should set up safe standards for the marine and air disposal of radioactive materals as soon as possible, based on current knowledge. Research in marine disposal should be carried out on a cooperative international basis.

- Records should be kept for each individual showing his total accumulated lifetime exposure to radiation. Medical use of X-rays should be reduced as much as is consistent with medical necessity.

- Techniques for monitoring world-wide fallout should be further improved. Measurements of the storage of radiation in the stratosphere should be extended.

rem total to age 30 for occupational groups. "If you average the 150 and the 15 for the total population, you still have a pretty darn low figure," Taylor observes.

The International Commission for Radiological Protection (the U. S. delegation to which is also headed by Taylor), when it met in Geneva in April, felt that for the time being it is not necessary for it to set maximum levels, although the time will come if nuclear-energy programs continue to be stepped up; that present levels of exposure are not too serious, and that if ICRP waits a few years it will be able to set figures that will not have to be changed for some time.

Taylor cautions against going to extremes in either direction: needless medical use of X-rays should be eliminated, but "the danger of a lot of people developing TB is worse than the potential danger of affecting the heredity of far-off generations." However there is considerable room for tightening protection in the medical fields: there are 65,000 dentists using X-rays, 20,000 general practitioners, 12,000 other physicians, 15,000 hospitals, 7,300 chiropractors, 3,800 osteopaths, 3,000 radiologists—and of these 126,100, only the 3,000 radiologists are required to have training in radiation use and protection. For a number of reasons, general practitioners are apt to expose both patients and themselves more than is medically necessary. On the other hand, X-ray shoe-fitting machines are "just sheer nonsense: all you can tell is that you have 10 toes, and that they're inside something." Taylor's middle-of-the-road, commonsense approach is exemplified by his comment on luminous-dial wristwatches: "If it serves a useful purpose, by all means have it; but if you only look at it in the dark now and then, why bother to expose yourself?"

AEC has already been trying to practice the reports' recommendation that occupational exposure records for each individual follow him from job to job through life, and plans to improve its system. But at present it is not considered either needful or feasible to keep records for the entire population. If, in the future, this should appears desirable, it will take "an enormous amount of education, control and regulation, will mean a large bureaucracy somewhere, and may cost $0.5-billion/yr." If the data is well kept and complete, it would require about 25 generations (750 years) to produce the kind of human genetic information needed for full understanding of radiation effects on heredity. Some countries are already attempting this: Sweden and New Zealand license every radiation source; but New Zealand has fewer sources than does General Motors Corp. in Detroit alone.

The report makes the point that release of a hazardous substance by any country may affect other countries, particularly in the same latitude belt; therefore, international control to establish and maintain high standards of safe plant operation is essential. Continuation of the present trend toward containment, and preliminary meteorological studies at proposed reactor sites are urged.

Reactor-waste processing plants or storage facilities are held to offer a greater hazard on a long-term basis than any single reactor. Development of improved methods to limit the volume of wastes produced in power reactors, and continuous appraisal of reactor and fuel-processing-plant design and operation as well as of waste storage will be required to keep world environmental radioactivity levels at tolerable levels. In addition, the report calls for "establishment, perhaps through private enterprise, of suitable waste-disposal services." Fission products from reactors at nuclear central stations and in naval service—the two predominant sources in the next decade—will amount to 10 kg/day by 1965, the report says, and must be kept out of the environment to maintain human exposures within permissible limits.

Rogers McCullough Heads AEC Safeguards Staff

C. Rogers McCullough, chairman of the Advisory Committee on Reactor Safeguards, has joined Clifford K. Beck (NU, May '56, p. 21) on the new AEC safeguards staff. McCullough will head the unit in the Division of Civilian Application, with the title of deputy director for hazards evaluation. He is on leave from Monsanto Chemical Co.

Perhaps the person in the country most prominently identified with reactor hazards problems, McCullough's work in this field goes back to 1950 when he was named chairman of the Industrial Committee on Reactor Location Problems that made extensive studies at Hanford and Brookhaven on fissionable material production facilities from both the plant and the community viewpoint. He has headed ACRS since it was set up by AEC in mid-1953,

Radiation Exposure Experience at Hanford . . .

Average Annual Exposure, Gamma Radiation

Year	Annual exposure (roentgens)	% exceeding 1 r	% exceeding 3 r
1944–45	0.9	0.2	0
1946	0.6	0.2	0
1947	0.4	0.3	0.02
1948	0.3	0.2	0
1949	0.2	0.08	0
1950	0.1	0.06	0
1951	0.1	0.4	0
1952	0.2	3	0.02
1953	0.2	5	0.07
1954	0.2	5	0.2

Annual Whole-Body Gamma Exposures above 1 r

	Number of cases (including all cases in columns farther to right)				
Year	>1 r	>2 r	>3 r	>4 r	>5 r
1944	0	0	0	0	0
1945	8	1	0	0	0
1946	8	2	0	0	0
1947	13	2	1	1	1 (6.1 r)
1948	10	2	0	0	0
1949	4	0	0	0	0
1950	3	0	0	0	0
1951	23	0	0	0	0
1952	179	22	1	0	0
1953	323	42	4	0	0
1954	372	68	16	3	1 (14.4 r)

Relative Hazard of Typical Operations

Type of work at Hanford	% > 1 r	% > 3 r
Engineering, research	1.7	0.2
Reactor operations	38.5	0.8
Reactor monitoring	36.9	11.9
Reactor maintenance	10.9	0
Separations operations	4.8	0
Separations monitoring	8.7	0
Separations maintenance	2.0	0
Radiation instrument calibration	58.2	0

. . . shows what can be done in radiation control at an installation large enough to "present collectively a good cross section of the radiation hazards that may be expected in peaceful applications of atomic energy," and eleven years' experience is long enough to be of statistical value. The magnitude of the radiation hazard at Hanford "can be described as the equivalent of handling some millions or tens of millions times the world's available supply of radium." The tables and quotations are from "Radiation Exposure Experience in a Major Atomic Energy Facility" by H. M. Parker of the Hanford Atomic Products Operation (Geneva conference paper P/240).

and just a month ago was elected president of the American Nuclear Society.

Japan Turning to Britain for 'Economic' Power Reactors

Japan will look to Britain for most of its nuclear aid in the future, unless the U. S. is able to match British offers, Matsutaro Shoriki, Minister of State and chairman of the Japanese AEC, told NUCLEONICS. Britain is now favored for two reasons, he said: 1. Britain says it can sell Japan a reactor at once that is capable of producing electric power on a commercial basis, while the U. S. has made no such offer; 2. Britain doesn't require—as does the U. S.—that technical information concerning nuclear equipment purchased be kept from the public. This question has important political implications, as the Socialists in particular are demanding publication of nuclear technical information.

Shoriki threw Japanese business and science circles into an uproar a month ago when he first indicated he felt the British were "well ahead of the U. S." in nuclear power development. A Japanese news agency survey showed industrialists there felt Shoriki's decision was premature. He had based it on talks with the U. K.'s Sir Christopher Hinton, and with Marvin Fox of Brookhaven National Laboratory, who recently visited Japan. Shoriki told NUCLEONICS he had asked Fox if the U. S. could meet the British offer but that Fox was noncommittal.

"Can the U. S. blame us for turning to Britain?" he asked. "If her offer is valid, Japan will be producing nuclear power commercially within five years. Up to now we didn't dream this would be possible for ten years."

A 9-man Japanese survey team will visit England shortly to check the terms of the British offer; if they are confirmed, Japan will order a reactor for delivery in 3½–4 years. The team will consider 45– and 100–Mw models, is expected to order the latter, for $41.7-million. (A USAEC official said he failed to see why a $417/installed-kw reactor was thought economic.) Shoriki said this purchase would not affect the order for a 500-kw water-boiler from NAA, but probably would result in abandonment of plans to buy a CP-5 in the U. S. "If we can buy a reactor that can produce nuclear power commercially, we won't need any more experimental reactors," he said.

About the Industry

New firms seen in fuel fabrication. Phillips Petroleum Co. has sent invitations to 23 firms to bid on supplying Al-clad and -alloyed enriched-U fuel elements for the Engineering Test Reactor now building in Idaho at NRTS; bids are due July 25. Nine of the firms were names relatively unfamiliar in the field: Brooks & Perkins, Inc., Detroit; A. O. Smith Corp., Milwaukee; Vulcan Machine Co., Waynesboro, Pa.; Whirlpool Corp., St. Joseph, Mich.; York Corp., York, Pa.; Baker & Co., Newark, N. J.; C. B. Christiansen Co., Newark, N. J.; Consolidated Western Steel division of U. S. Steel, Haywood, Calif.; Al-Fin division of Fairchild Engine & Airplane, Farmingdale, L. I. The others are: ACF Industries, B&W, Cook Electric, Daystrom, GE, GM, Koppers Co., North American Aviation, Combustion Engineering, General Mills, Metals & Controls, NDA, Sylvania, Westinghouse. Operators for AEC of the Materials Testing Reactor, Phillips is expected to operate ETR as well.

Two firms building new U-mills. Vitro and Union Carbide Nuclear are expanding mill capacity. Vitro Rare Metals Co. division of Vitro Corp. is doubling the size of its Canonsburg, Pa., plant. The addition, to be completed in eight months, will allow technical- and reagent-grade chemical production and permit the milling and processing of U, particularly residues; it also will use a recently-developed, more efficient solvent extraction process. Thus the $1-million-plus expenditure will establish the first commercial primary U-processing plant in the East. Previously, Canonsburg had been equipped for hydro-metallurgical processing of U ores and other metallic waste materials, and for refining and recovery of rare metals for industrial use. Carbide Nuclear has signed a contract with AEC for construction and operation by the former of a new U processing mill at Rifle, Colo., and two new ore receiving stations and chemical upgrading plants at Slick Rock, Colo., and Green River, Utah. The new mill will be 2 mi down the Colorado river from the existing Carbide Nuclear Co. mill at Rifle; lack of space and the tailings disposal problem led to the decision to build an entirely new mill—which will have a larger capacity—instead of expanding the old one. Construction on the three facilities is to start at once, for completion in the fall of 1957.

Nuclear look-see at Temco. Temco Aircraft Corp. of Dallas has engaged ORSORT-graduate Fred R. Grisak, formerly nuclear engineer at Wright Field and with Convair, to see what it can do in the nuclear field. His first tasks are to write a comprehensive report on the fields of nuclear activity where the firm might be able to compete, and to prepare a booklet for manufacturing personnel, such as shop foremen, on examples of using isotopes and nuclear techniques in the hope of stimulating thinking on ways of using nuclear devices to improve tools, techniques or products.

New firm in radioactivity field. New England Nuclear Corp. has been founded in Boston by the former heads of the inorganic and organic chemistry departments at Tracerlab. Edward Shapiro is president and Seymour Rothchild is technical director. The firm will specialize in the chemical aspects of radioactive materials and will manufacture labeled compounds, reference sources, and radioactivity devices. A comprehensive line of compounds labeled with C^{14}, deuterium, and tritium will be stocked; custom syntheses of compounds containing a variety of isotopes and radioassay services for C^{14} and H^3 will be done.

British Report Advances At Vienna Power Parley

(*A special* NUCLEONICS *report*)

VIENNA

A highlight of the Fifth World Power Conference here June 18–23 that commanded the undivided interest of all 2,500 participants was the fourth workday devoted to nuclear energy. Contrasting with the accent on nuclear science prevalent at Geneva last fall, emphasis here was on application to electric power production. Progress since Geneva has been great, it was generally felt. A special observer for NUCLEONICS reported these statements as most noteworthy:

• Calder Hall reactor "A," which went critical four weeks ago, is now completely charged. The critical size is slightly lower than estimated. The effectiveness of control rods were checked last week and it was found that they could handle more excess reactivity than planned. Commissioning tests were carried out "without any major difficulties" and gas flow is now being tested to establish experimentally whether vibrations may be set up during full flow operations. Theoretical and model studies indicate not.

• Forecasts of the next three U. K. reactors, which are being optimized in design for power production, were openly optimistic. Described as representing a "very marked advance" over Calder Hall, they will provide greater flexibility of operation and decisive reduction in capital cost. The reduction in capital costs is mostly accounted for by a marked increase in electric capacity which has almost doubled in the new reactors. The big question remaining is to establish serviceability of fuel elements, and the U. K. is devoting a large percentage of her research and development effort to the problem that is the key in achieving economic nuclear power.

Bids for two reactors for the U. K. Central Electricity Authority are being submitted by four British manufacturing groups and awards will be made this fall. The third power station for which a firm inquiry has been issued is to be built for the South of Scotland Electricity Board. Henderson of that Board reported it would include the reactors in the one station which is to have a total capacity of 200–300 Mw electric. The inquiry asks for a firm price with necessary guarantees on output and efficiency. Henderson also reported economic studies of "pumped storage" indicate that storage of off-peak power may be attractive in the South of Scotland Electricity Board system to enable high plant factor in the nuclear plant. Additional capital cost of providing pumped storage there is estimated to be about $98/kw of electric capacity, and would prove profitable after the first few years of operation.

• Credit for plutonium produced in U. K. power reactors was stated by Duckworth of the CEA to be "somewhat less" than the "equivalent cost of U^{235} from the British diffusion plant."

• Changes in moderator temperature from room to several hundred degrees C were reported by Dunworth of AEA to affect nuclear characteristics of plutonium (presumably by increasing resonance absorption) so as to reduce overall utilization of uranium by a factor of 10. Thorium was reported to be less significantly affected by increase in moderator temperature.

• Staebler of the U. S. AEC reported that experimental results in the U. S. reactor program "reinforce our belief that nuclear power will compete economically even in the U. S.," and added that it is "quite possible that present technology might provide competitive power in some places in the world." He gave a full and impressive description of U. S. experimental and power reactor development programs in the course of which he reported that the core of the EBR-1 which was somewhat melted by an unintentional power excursion had been successfully removed and will be replaced soon. Favorable comment was given by several speakers on the economics of using oil-fired superheat in conjunction with nuclear reactors. Milne of Consolidated Edison and Moore of Babcock & Wilcox in a prepared paper reported that use of oil superheat to reduce steam pressure at turbine inlet from 405 to 307 psia and to increase steam temperature at turbine inlet from 446 to 1,000° F would increase station gross electrical capacity from 140 to 236 Mw at an increase in capital cost of only $10-million. Total plant cost was thereby reduced from $322 to $233/kw of electric capacity. The oil-fired superheater was reported to have high efficiency and low heat rate of 7,700 btu/kwh. The overall cost of producing electricity at the Indian Point station was estimated at 8.8 mills/kwh at an 80% load factor.

• LeClair of Commonwealth Edison reported that the Dresden boiling water reactor design steam pressure has been raised from 600 to 1,000 psia and that uranium oxide fuel elements enriched to 1.5% will be used. Excluding $15-million research and development cost, Dresden station will produce power at an estimated 7.5 mills/kwh at a 60% load factor.

• Went of the Netherlands reported that the critical assembly for homogeneous suspension reactor has been completed recently.

• Ekefalk of the Swedish State Power Board stated plans for a 75-Mw heat reactor nicknamed "Adam" and for a 100-Mw electric capacity power reactor called "Eve." Both are normal uranium heavy-water moderated. Indications are that Eve will be CO_2 cooled, and Adam will be D_2O cooled. Both will probably utilize pressure tube rather than pressure vessel design. (NU, Dec. '55, p. 15; Jan. '56, p. 15.)

• Soviet Union representatives presented a review of the previously-announced Soviet program which envisages 2,000 to 2,500 Mw of capacity by the early '60s.

• The Austrian representatives stated that four of the 12 nations drafting the international agency charter had agreed to sponsor Vienna as headquarters of the Agency and urged further support. As these include the U. S. and USSR, choice of Vienna to be seat of the new agency is likely (NU, June '56, p. 24).

Teller Confident on Fusion; Predicts Direct Conversion

Project Sherwood is progressing, Edward Teller said at the ANS meeting in Chicago; he is confident controlled fusion will be mastered, but "in 100 years, or a few decades." In addition to the oft-stated advantages—"it would solve the fuel problem forever; no reprocessing; safer, because there's no tendency to run away, and far fewer radioactive poisons"—Teller declared success in controlling thermonuclear reactions would pave the way to direct conversion to electrical energy, without going through the thermal cycle, because of a direct link between the magnetic lines of force and the plasma. For just as the directed motion of currents can be used to create magnetic fields to contain the plasma, so the motions of the plasma—after the energy-producing fusions have taken place—can be used to generate directed electric currents.

Main difficulty, said Teller, is to confine the plasma and keep it at extremely high temperatures in a wall that won't take up heat. One way is to confine it in a "magnetic bottle"—within lines of force. The problem is to make this "bottle" leakproof; the lines of force behave like rubber bands, trying to snap inside, letting the plasma out. Sherwood is studying the way in which the leaks are sprung, to find ways to overcome them. Hearers expecting a reply to the Kurchatov speech were disappointed; Teller said he spoke under policy rules set down prior to Kurchatov's talk.

Washington Report

The status, rate of progress, and future direction of the nation's nuclear power program loomed large in the closing sessions of the 84th Congress. Here is a roundup of major legislation as it stood as of July 12th, with the outlook for final action before adjournment.

The Gore bill (S. 4146) as revised and passed 14–0 by the Joint Committee on Atomic Energy would supplement private industry reactor-development programs by an AEC program of large-scale prototype nuclear power plant building (p. R1). Strenuous efforts were underway to schedule it for Senate and House debate in mid-July; chances of passage appeared favorable, with opposition expected from Republicans.

The Federal indemnity bill (S. 4112) provides for the government to make up to $500-million available to cover public liability claims arising out of possible nuclear "incidents," over and above the $65-million provided by the private insurance industry for each nuclear plant (NU, June '56, p. 20B). A fee of $30/yr per Mw of thermal capacity on section-103 facilities has been set for the government indemnity. The bill has been passed by JCAE and efforts were being made to schedule it also for floor debate in mid-July. By itself it would be a cinch to pass, but Gore-bill foes tend to view the two as parts of an undesirable whole.

Holding Company Act amendment (S. 2643) would exclude from regulation under the 1934 Holding Company Act firms that are not utilities but that participate in nuclear-power-demonstration projects during their research and development phase. This has been approved by JCAE; eventual Congressional passage appears to be merely a question of time—of getting done before Congress adjourns. Chances are fair to good.

A joint resolution by Rep. James E. Van Zandt (R-Pa.), a JCAE member, calls for establishment of a nine-man commission to appraise the progress and direction of the U. S. nuclear power program. Born of doubts raised in Congress this year about the country's world leadership in nuclear development, the resolution calls for a report to Congress by January 1957; members of the group—experts in nuclear science, engineering, economics, and electric-utility operation—would be appointed one-third each by the President, the Senate and the House. No action in JCAE is expected.

Nuclear merchant ship bill (H.R. 6243) has been passed by both House and Senate but in varying versions that are to be reconciled in bicameral conference committee. Remaining to be decided are the type of vessel (JCAE chairman Anderson and the Maritime Administration favor a tanker, some others a dry-cargo ship); and the type of reactor (Anderson wants an improved *Nautilus* PWR, which might take a year to design; a "Chinese copy" of the *Nautilus*' plant would be faster to build but would not advance the art). Passage of some compromise version appears a good bet.

Salary increase bill (S. 4162) would raise AEC chairmen from $20,000 to $25,000 a year, commissioners from $18,000 to $22,500, and give corresponding increases to the general manager, division directors, and a number of other AEC executives. Passage is contingent on success of the analogous federal executive pay bill, which the Senate civil service committee has not rushed to approve.

An omnibus bill, containing odds and ends such as changes regarding jurisdiction of AEC Western lands, contains one significant item: authorization for AEC to give grants to colleges and universities for building research reactors and other training facilities, or giving scholarship aid. It is a good bet to pass.

Report from Britain

LONDON

British scientists are becoming increasingly confident that their step-by-step approach to Britain's extensive nuclear power program is the correct one. The whole concept is aimed at achieving a progressive reduction in reactor core size with ascending scale of enrichment and specific fuel rating. Construction is so phased that experience from each station will diminish the chances of a wrong turning.

Dounreay, the fast reactor, is the only manifestation of any leap-frogging in the whole $900-million program and this is being built with full realization that many fundamental metallurgical problems will persist after its commissioning. Dounreay, of course, will utilize plutonium from the Phase 1 reactors.

At least eight of the 12 power stations forming Phase 1 of the program will be based on the Calder Hall gas-cooled graphite-moderated type but will increasingly embrace new developments as the program progresses.

Referring last month to Britain's policy, F. M. Greenlees, top consultant of the Atomic Energy Authority, stated: "It is more important to be safe than clever for our first power generating reactors. Therefore we should content ourselves with securing reliable operation at modest temperatures."

The British now feel that the most promising avenues towards improving reactor efficiency are these:

1. Development of improved on-site welding techniques enabling use of 3-in. plate in pressure vessel fabrication.

2. Switch to hydrogen coolant—if metallurgical problems can be overcome.

3. Use of slightly enriched uranium sufficient to permit use of canning materials previously rejected on grounds of high neutron capture. This will enable at least a modest rise in the operating temperature of the fuel elements. Alternatively, enriching the charge towards the outside of the core evens out the flux distribution in the core and increases thermal capacity.

4. Development of lighter, cheaper, and more compact heat exchangers.

5. Increasing the life of fuel elements and reducing cost of reprocessing.

Calder Hall is already pushing large pressure-vessel fabrication to the limits. Main obstacle is inability to weld plate greater than 2-in. thick on site. Welding techniques capable of working in the field with 3-in. plate are expected shortly that will enable either large reactors offering lower capital cost per kw; or, with the same size, upping the gas pressure which reduces the pumping horsepower required.

Possibility of an improved coolant for at least the first eight reactors is restricted to hydrogen. Helium, since it is not indigenous, is too costly. Hydrogen offers a number of advantages. It requires only one-tenth the pumping horsepower required by CO_2. And since to a certain extent it acts as a moderator, it reduces graphite needed and hence lowers structural cost. Also, a loss of coolant reduces the pile reactivity.

The adoption of hydrogen will depend on overcoming several metallurgical disadvantages, among them a tendency for hydrogen to attack the uranium and diffuse through the cans. The possibility of H-embrittlement of the reactor structure also cannot be overlooked.

To avoid delay in the program, Calder Hall designers chose to use available components and fabrication techniques in the construction of the heat exchangers even though this meant the units would be costly, bulky and difficult to erect. Each of the four exchangers weighs 200 tons, is 18 ft in diameter and 70 ft high. They have mild steel tubes of 2-in. dia. with the outside gas surface extended conventionally by elliptical steel stud tube fin construction that is not the optimum for pure gas/water heat transfer. Improved heat transfer surfaces are certain to be incorporated in later designs, leading to cheaper and more compact units.

With the cost of processing fuel elements a substantial item in the over-all cost, intensive efforts are being made to extend their life and reduce the cost of processing. Harwell is now using high-temperature metallurgical processes in an attempt to avoid the conventional metal-solution-metal methods. The fuel is kept in the metallic state and melting, slagging, and vaporizing techniques are used to remove the neutron absorbers.

Exactly how all these developments will be phased into the British program is not certain, but some certainly will become manifest in the middle four units—due for commissioning in 1963. Trend to fuel loadings higher than the 1 Mw/ton of the Calder Hall unit and coolant temperatures approaching 900° F should be established. The first four stations after Calder Hall are certain to be CO_2-graphite units built in pairs, 18 months apart starting 1960.

After 1963, the metallurgists do not rule out the use of sodium coolants and graphite moderators in the last four reactors of Phase 1 development. These are due for commissioning in 1965. Higher fuel temperatures also will call for cans of zirconium, beryllium, or niobium to replace light alloy used in the Calder Hall cans. Harwell has made extensive contributions to the metallurgy of these metals in recent years.

Design of Phase 2 reactors is now officially reduced to choice of sodium- or water-cooled reactors. Based on the final assessment, one prototype station is to be built by 1960, and the closing years of the next decade might well see the end of the gas-cooled reactor. This stage will use plutonium bred from Phase 1 reactors to enrich the uranium. Coolant temperature should be about 900° F and specific fuel loading "several Mw per ton."

Little information is yet available on progress of the homogeneous reactor in the chemical division at Harwell but it represents very longterm thinking.

In support of the whole program, three more research reactors are being built at Harwell: Dido, Pluto and Lido. Payoff of all this effort begins in October when Calder Hall, world's first large-scale nuclear power station, goes into operation.

TABLE OF BRITISH REACTORS

[prepared with the assistance of Harwell staff]

Function	*Startup*	*Moderator*	*Coolant*	*Fuel*	*Neutron energy*	*Location*	*Power*		*Cost*	*Peak flux* ($n/cm^2/sec$)
							Heat	*Elec.*		
GLEEP (Graphite Low Energy Experimental Pile)										
Research	1947	graphite	air	12 T nat'l. U metal bars & 21T U_3O_8	thermal	Harwell	<5 kw since operation of BEPO	0	?	$<2 \times 10^9$
BEPO (British Experimental Pile)										
Research	1948	graphite	air	40 T nat'l. U	thermal	Harwell	6 Mw	0	?	2×10^{12}
DIMPLE (Deuterium Moderated Pile Low Energy)										
Reactor physics research	1954	D_2O	none	Capable of using a variety of fuel types & arrangements	thermal	Harwell	<100w	0	$140,000 excl. fuel, D_2O & g'ph'te reflector	$\sim 10^8$
ZEPHYR (Zero Energy Fast Reactor)										
Reactor physics research	1954	none	none	Ni-sheathed Pu rods; U blanket	fast	Harwell	2–30w	0	?	$\sim 10^9$
ZEUS (Zero Energy Uranium System)										
"Full-scale model" to check nuclear calculations for Dounreay	1955	none	none	20 × 20-in. cylindrical core containing very highly enriched U; "many tons" nat'l. U blanket	fast	Harwell	<100w	0	?	$<5 \times 10^9$
ZETR (Zero Energy Thermal Reactor)										
Homogeneous reactor physics research	1955	D_2O or H_2O	none	Pu, U^{235} or U^{233} in solution	thermal	Harwell	0	0	?	$\sim 4 \times 10^5$
DIDO (formerly designated E-443)										
Materials research	mid-'56	D_2O	D_2O	Highly-enriched U-Al alloy with 2.5 Kg U^{235}	thermal	Harwell	10 Mw	0	5.5×10^6 excl. fuel	10^{14}
PLUTO (2) (formerly designated RE-775)										
Materials testing (6 loops)	end '57	D_2O	D_2O	as in DIDO	thermal	1 at Harwell, 1 at Dounreay	10 Mw	0	?	10^{14}
LIDO										
Shielding research	1956	H_2O (swim. pool)	H_2O	3 kg highly enriched U-Al alloy	thermal	Harwell	100 kw	0	?	10^{13}
Windscale (2 identical)										
Pu production	1950, 1951	graphite	air	nat'l U	thermal	Windscale, Cumberland	?	0	?	?
PIPPA Mark 1 (Calder Hall) (2 identical)										
Pu + power	1956, 1957	graphite	CO_2	nat'l U.	thermal	Calder Hall, Cumberland	?	65 Mw net	$42–56 × 10^6	?
Dounreay										
Experimental breeder	1957?	none	Na or NaK	U enriched with U^{235} or Pu	fast	Dounreay, Caithness	60 Mw	?	?	$\sim 3 \times 10^{15}$
Calder Hall-type (6 identical)										
Pu + power	1959–1960	graphite	CO_2	nat'l U.	thermal	2 at Calder Hall, 4 at Chapelcross, Dumfriesshire	?	Total 200 Mw net	?	?
PIPPA Mark 2 (4 identical; advanced Calder Hall type, first in 10-year program for Central Electricity Authority)										
Power + Pu	1960, 1961	graphite	gas	Nat'l or slightly enriched U	thermal	2 at Bradwell, Essex; 2 at Berkeley, Gloucestershire	?	50–100 Mw/reactor	$84–98 × 10^6	?

Reactor News

Nuclear ship studies ordered. The Maritime Administration is letting contracts for four studies on advanced nuclear ship propulsion plants. These advanced, or Phase-2 (NU, May '56, pp. 20, 73) studies are with AMF Atomics on a closed-cycle boiling-water system; Atomics International for an organic-moderated; and Ford Instrument Co. and General Motors, both on direct closed-cycle gas-cooled plants. In addition, MA is having Babcock & Wilcox carry out a study on a Phase-1 pressurized-water plant, just to keep PWR technology current.

HRE-2 nearing completion. Construction work on the second homogeneous reactor experiment at Oak Ridge has been completed and the construction workers have moved out of the building. The entire system has been subjected to hydrostatic pressure testing (there are three miles of leak-detection tubing in the plant, all pressurized with gas); criticality is scheduled for October.

Reactor for Tuxedo Park? Union Carbide Nuclear Co. is planning to build a research reactor; one site under consideration is in the Ramapo mountains of Orange county, near the onetime social center of Tuxedo Park, N. Y.

Portable reactor by Aerojet. A light, portable reactor for hospitals, industries and universities has been designed by Aerojet-General Nucleonics, new subsidiary of rocket-making Aerojet-General Corp. Technical details will be published in September NUCLEONICS. AGN, with headquarters, lab and plant at San Ramon, 25 mi E of San Francisco, and a test site near Sacramento, will make power and component-test reactors also.

Gas-cooled experiment for NRTS. A $4-million experimental gas-cooled power reactor will be built by AEC at the Idaho testing station. Proposals for design and construction will be asked shortly.

ETR design changed. AEC's contract with Kaiser Engineers to design and build the Engineering Test Reactor at NRTS has been modified to add experimental loops "for tests of interest to the aircraft nuclear propulsion program." They will add $3-million to the $15-million cost of the reactor.

Armour reactor critical. Two weeks after being granted a 10-yr operating license by AEC, Armour Research Foundation's $700,000, 10-kw water-boiler went to work as the nation's first private reactor for industrial research. Built by Atomics International (NAA), the facility in the heart of Chicago's south side is also the first reactor in a densely populated area.

The last shall be first. Yankee Atomic Electric, last of the first-round demonstration proposals to be accepted by AEC as a basis for negotiations (NU, March '56, p. 22), was first to complete a contract with AEC. Yankee will get $5-million worth of research and development aid from AEC toward the $18.5-million cost of the reactor portion (total plant cost will be $34.5-million); AEC also will waive fuel charges during construction, testing and the first five years of operation. Westinghouse is development and design agent. Major construction is to start on the Rowe, Mass., site in spring, for 1960 completion. A pressurized-water type, the 134-Mw reactor will use a new type of core (NU, May '56, p. 22) that "promises improved economic performance and may bring us within striking distance of competitive power," says Yankee head William Webster.

Boiling study at Battelle. AEC has contracted with Battelle Institute for critical-assembly studies of a small heterogeneous boiling-water reactor for military application, to determine the range of usefulness of control by reflector rather than by control rods.

Reactor Constants Center founded. Argonne National Lab has set up a Reactor Physics Constants Center to measure, compile, and publish a wide range of constants. The work will be declassified and will serve Canada as well as the U. S.

Wright Field reactor bids fail. The Air Force will have to readvertise for bids on its tank-plus-pool research reactor and labs (NU, May '56, p. 22). Four bids were received; the lowest ($12,177,039) was $5-million over the $7.5-million authorized. Penalty clauses and a short (18 mo) construction period scared the bidders, it's felt. The high-level-radiation building and waste disposal plant are deferred, and new bids, due in August, will allow 24 months for building the rest; a contract is to be awarded by Sept. 30, making completion lag 9 mo behind original schedule. It is noteworthy that all four bidders were construction contractors, with the usual reactor manufacturers in the role of subcontractors.

Progress report of PWR. H. A. Bethel of Westinghouse told the ANS meeting in Chicago that PWR is at the height of construction activities in the field, with components being delivered to the site daily. All fluid systems designs have been frozen and essentially all components are on order; the various fluid systems are now being reviewed for compatibility of the many interconnections to assure properly integrated performance of the plant. Electrical and control systems, somewhat behind fluid systems in status, are just now in process of being frozen with many component specifications yet to be completed. A major problem, he revealed, has been procurement of relief valves, especially those to relieve the water system. Because of the requirement for exceptionally tight reseating—a quality notably lacking in conventional water reliefs—suppliers have been reluctant to take on these valves except on a developmental basis; a development program is now underway. A related problem is the lack of a facility to test steam and water relief valves at the pressures and relieving capacities required to verify satisfactory operation. A relief-valve test facility is now being designed for installation this fall at the Mishawaka station of American Gas & Electric to test valves for PWR and other Bettis projects. Design of the fuel elements has been fixed and manufacturing is in process, as it is also for other core components, core structural supports, control rods, rod drive mechanisms, etc. A full-scale critical assembly has yielded necessary data on reactivity, control-rod worth, and core loading; during this summer and fall it will be used to obtain flux plots to fix the extent of orificing necessary to provide proper distribution of the water flow through the regions according to the rate at which they generate power. Installation of plant components will begin in midsummer and be completed in winter; integrated testing of the plant without core will be done next spring; core manufacturing will be completed next summer, and the plant is to be in operation by the end of 1957.

World News

French back Euratom. What was considered the greatest obstacle to establishment of Euratom was hurdled when the French National Assembly approved, 342–183, the principle of French participation in the supranational pool together with West Germany, Italy, Belgium, Netherlands, and Luxembourg. However, the Assembly exacted two concessions: France will renounce her right to develop nuclear weapons only for an initial four-year period, and Euratom will not be governed by the same bodies as administer the six nations' coal-steel pool.

Power reactor for Belfast. Northern Ireland is planning a nuclear power station costing $184-million, to go into operation late in 1963.

Nuclear power for Okinawa asked. Rep. Melvin Price, head of the research and development subcommittee of the Joint Committee on Atomic Energy, urged that a 44 Mw power plant now needed on Okinawa be nuclear rather than oil-fired; the high cost of shipping oil from the Persian Gulf would make it competitive, he said.

Czechs making heavy water. The Chemical Ministry in Prague said Czechoslovakia will begin producing D_2O this year.

Hammarskjöld names radiation aides. Raymond K. Appleyard of Britain, Henri P. Jammet of France, and Eizo Tajima of Japan will be the scientific secretaries of the U. N. committee on the effects of radiation (NU, April '56, p. 24).

Mexico names Commission. President Adolfo Ruiz Cortines appointed a three-man Nuclear Energy Commission, a step awaited since January. Named were José Maria Ortiz Tirado, lawyer and diplomat, former president of the Mexican Supreme Court and ambassador to Colombia and Peru; Nabor Carrillo, rector of Mexico's National University, delegate to the United Nations Atomic Energy Commission in 1946, and head of the Mexican delegation to Geneva last August; and Manuel Sandoval Vallarte, Undersecretary of Education, physicist and former professor at MIT. Ortiz Tirado is chairman, but President Ruiz Cortines himself will serve as ex-officio head of the NEC to make or clear all important decisions. Appointments are for the present administration's tenure in office, that is, until December 1958; but as all three appointees are relatively nonpolitical, continuity in the panel is expected. One of the group's first considerations will be a power bilateral with the U. S.

U. K. insurance men optimistic. Insurance of risks from industrial use of nuclear energy is a "practical possibility," says the British Insurance Association, for "precautionary safeguards are so great that the risk of a catastrophic accident is remote. . . . The fire and explosion hazards involved in the operation of the new atomic power stations in Britain will be little different from those encountered in many modern industrial or power plants. There is, however, a new hazard in the shape of possible radioactive contamination . . . "

Forecast for Australia. Within 50 years, Australia will be producing 60% of its power requirements from nuclear sources, says Australian AEC deputy chairman Baxter. In the year 2000 her total power requirement will be more than 20 times the present need, or about the present U. S. power capacity. To meet this, Australia would need to produce 20,000 metric tons of U or 10,000 of Th, he said.

Industrial atomic disease conference planned. The picturesque, 38 mi² republic of San Marino, the enclave in NE Italy, has called a conference for April 1957 on "The Prevention and Treatment of Atomic Diseases of Industrial Origin." It will cover atomic pathology; training of medical specialists and auxiliary staff; standardization of radiological units; coordination of studies on the therapeutic effects of radiation on individuals and on the species, and radiation effects on nutrition; and circulation of information on medical problems related to nuclear power. Governments will be invited to send doctors and students.

Austrian Study Society for Atomic Energy Ltd. organized. The Österreichische Studiengesellschaft für Atomenergie GmbH, invitations to join which went out six months ago (NU, Feb. '56, p. 15), has been formally established. The government purchased 51% of capitalization shares ($121,000 worth, as against $119,000 taken by industry). Rudolf Stahl, director general of the Austrian Grid Co., is chairman of a board of directors to which the government named 14 representatives, industry 12, and science one.

Dominican Republic buys power reactor. Beating out several longer-touted projects, the Dominican Republic became the first Latin American country to buy a power reactor last month. Generalissimo Trujillo announced his government had contracted with Glenn L. Martin Co. for a 12-Mw pressurized-water reactor. It will increase the present electric capacity of the country from 45 to 57 Mw. More than 5,000 fuel elements of slightly-enriched U will be needed. The contract is contingent on completion of a power bilateral.

Lithium in Rhodesia. Deposits of lepidolite and petalite at Bikita, Southern Rhodesia, have proved to be large and possibly among the richest in the world, reports chief government mining engineer W. Ralston. Lithium metal is not yet being produced in the country, but some of the present small local output at Gwelo is being processed for production of Li salts. Last year 82,166 tons of Li ores were mined in Southern Rhodesia—$900,000 worth.

Geneva reactor's second home progressing. The foundations have been completed for the permanent home of the U. S.-built swimming pool sold to Switzerland after the Geneva conference, and the concrete floor for the second story has been poured at the Würenlingen site 30 km NW of Zürich. The reactor is scheduled to be back in operation by Christmas.

Belgium gets accelerator. The Liège Center of the Belgian Inter-university Institute for Nuclear Sciences has completed installation of a 2-Mev Van de Graaff, built by High Voltage Engineering Corp. and the Ateliers de Constructions Electriques de Charleroi. The American company, holder of patents on the machine, consented to having some of the equipment built in Belgium.

Poland starts reactor construction. Building has begun at the Central Atomic Center near Warsaw using Russian blueprints. The center will have a research reactor, a nuclear physics lab, and a radiochemistry lab. The first parts of the 2-Mw, 10^{13} n/cm²/sec water-moderated and -cooled reactor will arrive from Russia this year, and operation is scheduled for mid-1957. The reactor is presumed to be the same model that the Soviet is supplying Czechoslovakia (NU, April '56, p. 19).

ROUNDUP

News in Brief

Health physicists organize. The first, constituent meeting of the Health Physics Society at Ann Arbor elected Karl Z. Morgan of Oak Ridge president; he had served as temporary president during group's organizational period. 250 health physicists attending the meeting discussed survey instrumentation, radiation protection, and metabolism of radioisotopes.

Con Ed progress. Frank Ward has been named project manager by Babcock & Wilcox for the Indian Point plant. Westinghouse will supply the turbogenerator.

Two new activities. Superior Tube Co. of Norristown, Pa., has set up a nuclear products division. The company has experience in making exacting-tolerance tubing for reactors and in processing zirconium and other nuclear metals; it will also supply control rods, rod channels, and other components. Technical Operations, Inc., of Arlington, Mass., has signed a contract with AEC to do operations-research on the reactor-safety program.

Buffalo U. gets help. Bell Aircraft Corp. of Buffalo has pledged $75,000 toward Buffalo University's $750,000 nuclear-research center.

Utilities plan studies. Worried by the Gore bill, the Edison Electric Institute decided to set up a technical appraisal task force to recommend reactor types that merit development, and to call a conference of utility presidents to study the U. S. nuclear-power program.

AEC lends U for teaching. Neutron sources and 8,000 lb of natural U—5,500 to Florida Univ. and 2,500 to Virginia Polytechnic Institute—have been lent by AEC for subcritical assemblies used in nuclear-engineering instruction. AEC also announced availability of improved Po-Be sources for educational institutions.

Incident at Sylvania. The four men still hospitalized after the July 2 blast at Sylvania's metallurgical lab in Bayside, N. Y., are recovering. The thorium explosion occurred when metal scrap was being burned to convert it to oxide for safer storage—a routine operation long used at Sylvania and elsewhere, with Th, Zr, and U. "Ordinarily it just glows, but this batch seemed to react rather violently," a Sylvania official said. Lab operations are back to normal. The blast was covered completely by routine insurance; damage, not yet fixed, run to five figures. Radioactivity, released only inside the lab, was negligible.

Industry takes step toward standardization. Speaking through the Standards Council of the American Standards Ass'n., industry voted to set up a new nuclear energy standards board within ASA. Action came on a report by Morehead Patterson, head of AMF and chairman of a planning committee on standardization in the field of nuclear energy, set up at an industry conference last December (NU, Jan. '56, p. 10; March, p. 24).

General Dynamics gets San Diego green light. About 85% of the voters of San Diego approved a special ballot proposition to transfer city-owned mesa land on the city's northern limits, adjacent to Torrey Pines State Park, to General Atomic division of General Dynamics Corp. for construction of a nuclear research laboratory (NU, April '56, p. 21-B). GA plans to break ground in a few weeks and to have the first building phase completed by 1957. Meanwhile, Dynamics' Electric Boat division at Groton, Conn., is building a $500,000 3½-story building containing 35,000 ft² for its design department. Completion is scheduled for October. Three more A-subs are in the works at Groton following *Nautilus* and *Seawolf;* design personnel alone now totals 1,350, five times its size five years ago.

Nuclear combine in Minnesota. Minnesota Nuclear Operations Group—23 business and industrial firms banded together for research—have made a $65,000 grant toward construction of a gamma-ray facility on the University of Minnesota campus, for work in engineering, medicine, biology, and agriculture. It will be operated by the Institute of Technology, to study applications of irradiation in solid-state physics, materials, radiochemistry, medicine, and food preservation, among others. The group was organized (NU, June '55, p. 20) by Northern States Power Co., Minneapolis-Honeywell Regulator Co. and General Mills; 20 more industrial firms, banks and insurance companies were taken in this year.

Summer course at Michigan. An intensive course in nuclear reactors and radiations in industry, designed for practicing engineers and management specialists, will be offered Aug. 20–31 at the University of Michigan.

Graduate training at Los Alamos. The University of California, which operates Los Alamos Scientific Laboratory for AEC, and the University of New Mexico have completed an arrangement whereby the latter will establish and operate a graduate training center at LASL, beginning with the 1956 fall semester. It will offer a program of courses leading to an M.S. in physics, chemistry, math, or engineering.

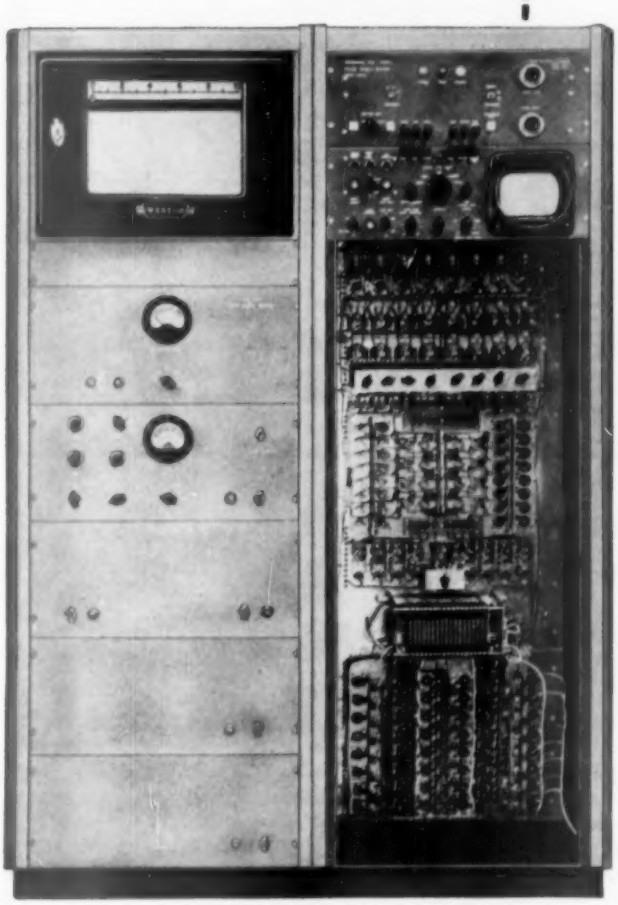
Accelerators in the oil fields. Magnolia Petroleum Co. has bought a 2-Mev Van de Graaff from High Voltage Engineering Corp. for use in its field research laboratory at Dallas. Magnolia was the first oil company to use a particle accelerator in well logging studies, beginning in 1953 with a ½-Mev Van de Graaff. It found success in applying the unit to analyzing elements in core samples, cuttings, crude oils, and other earth specimens; lab data suggest a basis for several new types of radioactivity logs to give elemental analysis in the bore-hole.

Remote fuel fabrication for Detroit breeder. Atomic Power Development Associates has let a contract to National Research Corp.'s equipment division to study the problems of remote fuel-element fabrication for the Detroit fast breeder. Since this reactor will involve a high fraction of fissionable material in the fuel and relatively low burnup, short-cycle pyrometallurgical reprocessing of fuel becomes economically desirable. The high radioactivity of the fuel necessitates remote facilities throughout the process. Problems to be studied are not limited to remote and automatic control of processing steps, but include consideration of possible adverse effects of radiation on components. NRC will try to develop specifications for modifying standard commercial equipment wherever possible, and to provide special designs to withstand the very high levels of radiation. The plant is designed to operate with minimum attention for long periods. Meanwhile project head Walker L. Cisler announced a turbine-generator for the fast breeder plant had been ordered from Allis-Chalmers (NU, April '56, p. 22).

RCL Mark XX Multi-Channel Analyzer

model 2603

A 256 Channel Analyzer based on the Argonne National Laboratory Design



- Permits automatic subtraction of background from the spectrum read out.
- Permits section storage for separate isotopes. Average dead time of the counting channels is reduced when only the first 128 channels are used.
- Provision for decimal printout with auxiliary circuit is available.
- Records a permanent plot of the spectrum.
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Specifications

1. 256 channels, each with 65,536 count capacity. **2.** Linearity 0.2% of full scale (except first 2 channels). **3.** Channel dead time 20 microseconds plus 0.5 n microseconds, where n is the channel number. Average dead time is less than 80 microseconds. **4.** No channel width adjustment needed—no channel width drift. Positional drift small and uniform. **5.** Channel width approximately 0.2% of full scale. **6.** Cathode ray tube display of data available during accumulation and readout — clearly shows the data in each channel. **7.** Permanent record of accumulated data available with precision pen recorder. **8.** 100-kc pulse generator for decimal conversion. **9.** 1000 VA Sola transformer for voltage regulation. **10.** Standard power cable has three-prong connector with provision for grounding.

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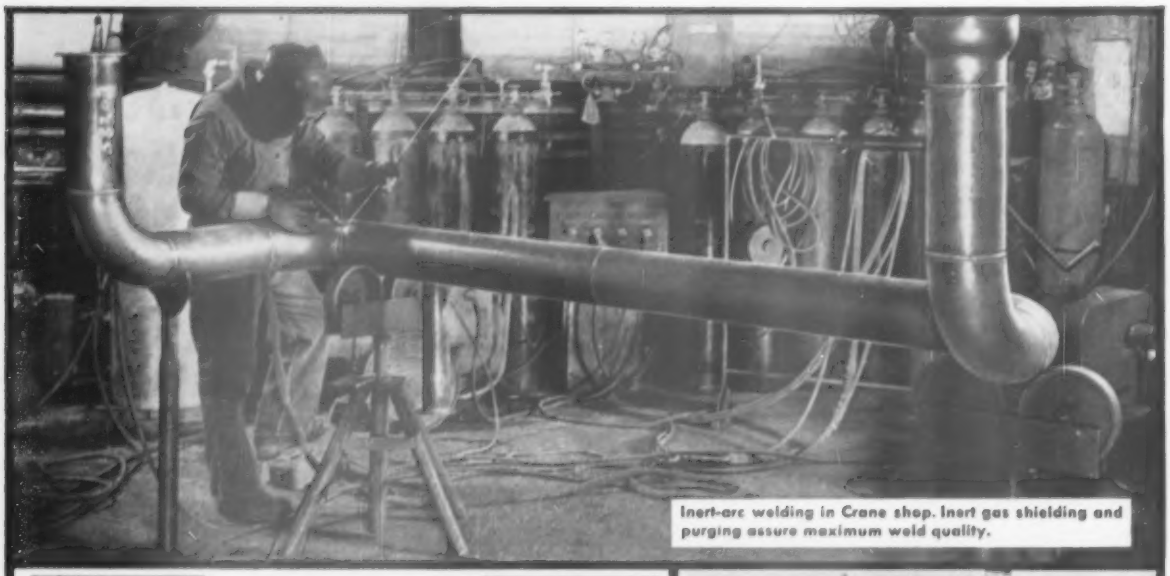

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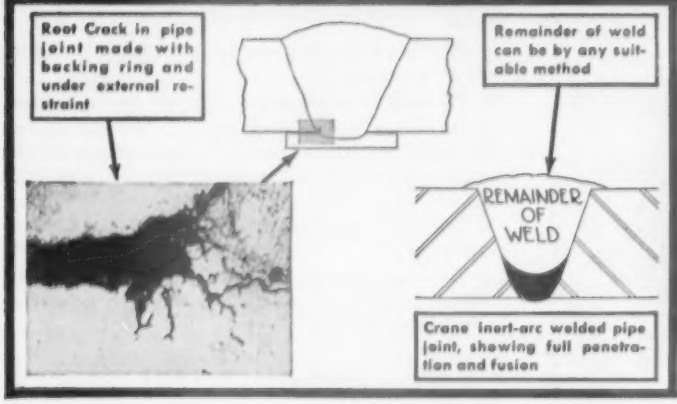
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U. S. Army Photo

• One of eight permanent Ordnance Corps arsenals, Redstone is the center for the Army's rocket and guided missile program. Its 40,000 acres are located on the Tennessee River near Huntsville, Ala., and house research laboratories, environmental test equipment and several rocket-testing ranges. Redstone Arsenal's military and civilian scientists and engineers produce weapons ranging from a tiny training rocket to the giant IRBM, now being developed on a crash basis by the recently-established Army Ballistic Missile Agency.

From the research, development, production and field service headquarters located at Redstone flow thousands of directives covering the rocket and guided missile work being done by research laboratories, universities and private industry throughout the nation. Weapons systems developed by this Ordnance-Industry team include the Super Bazooka infantry rocket, the Honest John artillery rocket, the Corporal missile and the Nike anti-aircraft missile.

Scientific barriers of all kinds are being broken by the 9,000 employees of Redstone Arsenal, but the exciting and difficult technology of guided missile development constantly presents new problems. Electronic computers click away at missile trajectory formulas by day, while at night rockets equipped with headlights streak down-range, adding valuable data to our country's newest arsenal of defense.

REDSTONE BALLISTIC MISSILE — This long-range rocket-powered, bombardment weapon was developed by the arsenal's guided missile team headed by Dr. Wernher von Braun. The Redstone is the progenitor of the Army's IRBM, the Jupiter.

This is one of a series of ads on the technical activities of the Department of Defense

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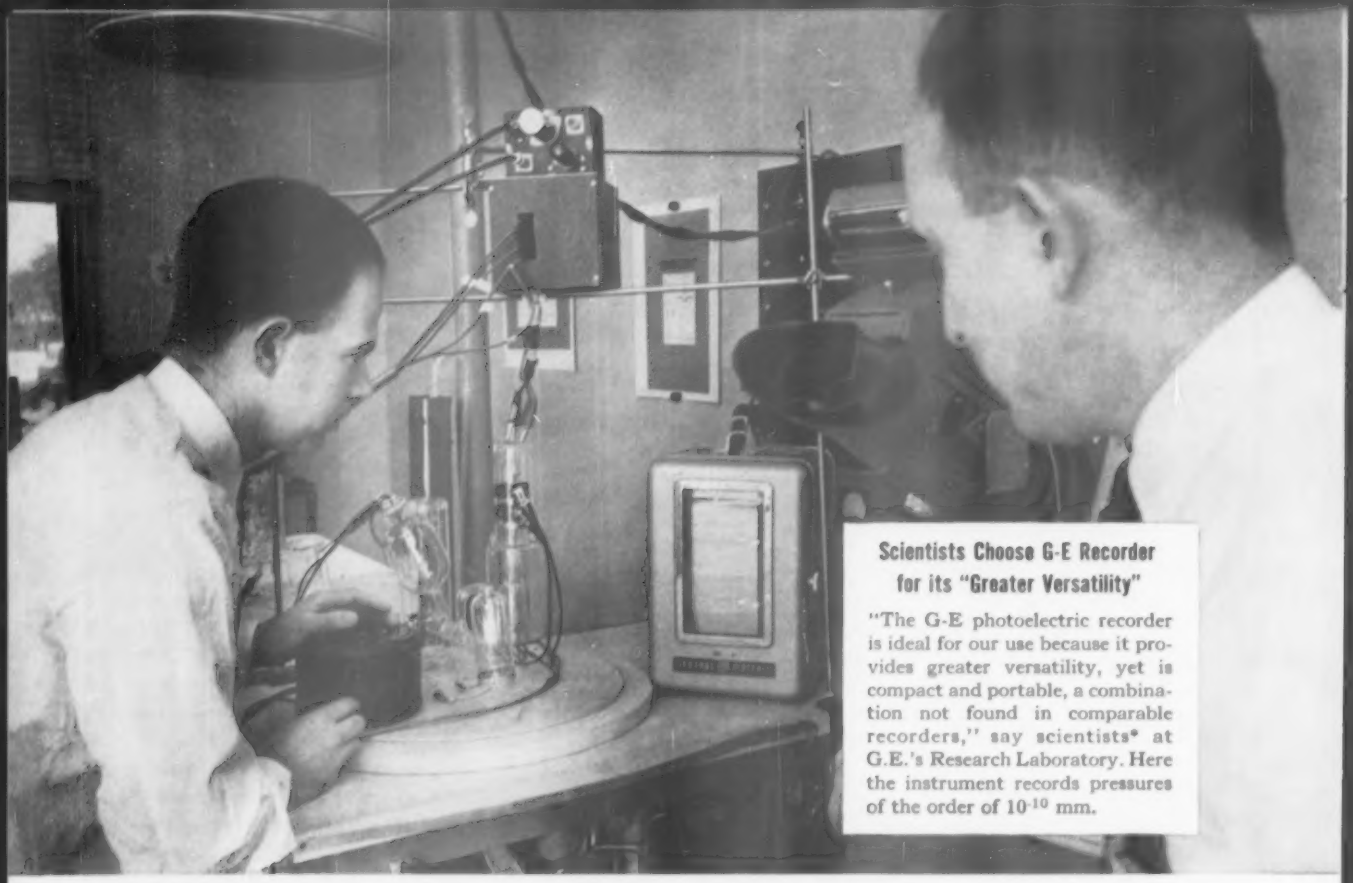

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General Electric's photoelectric recorder enables you to directly record electrical and transduced non-electrical quantities without additional amplification. This portable recorder offers high speed of response (up to 0.2 seconds full scale) and extreme versatility because:

A WIDE RANGE OF SENSITIVITIES is available with the G-E photoelectric recorder—as low as 1.0 ua or 0.2 mv for full-scale deflection. Here are just a few standard ratings available:

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FULL SCALE SENSITIVITY (microamperes)	COIL RESISTANCE (ohms)	FULL SCALE RESPONSE TIME (seconds)
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10.7	650	1.56
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*Dr. N. R. Whetten (left) and Dr. A. B. Laponsky (right), Research Associates at the General Electric Research Laboratory.

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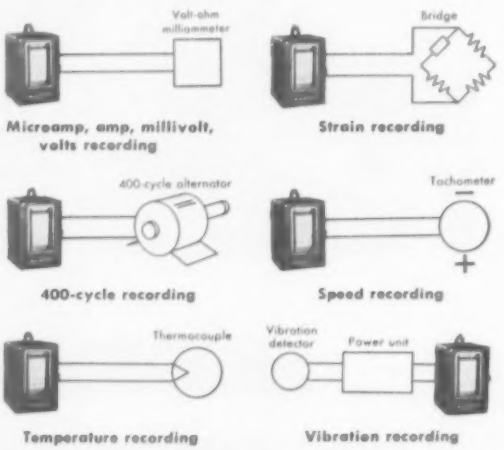

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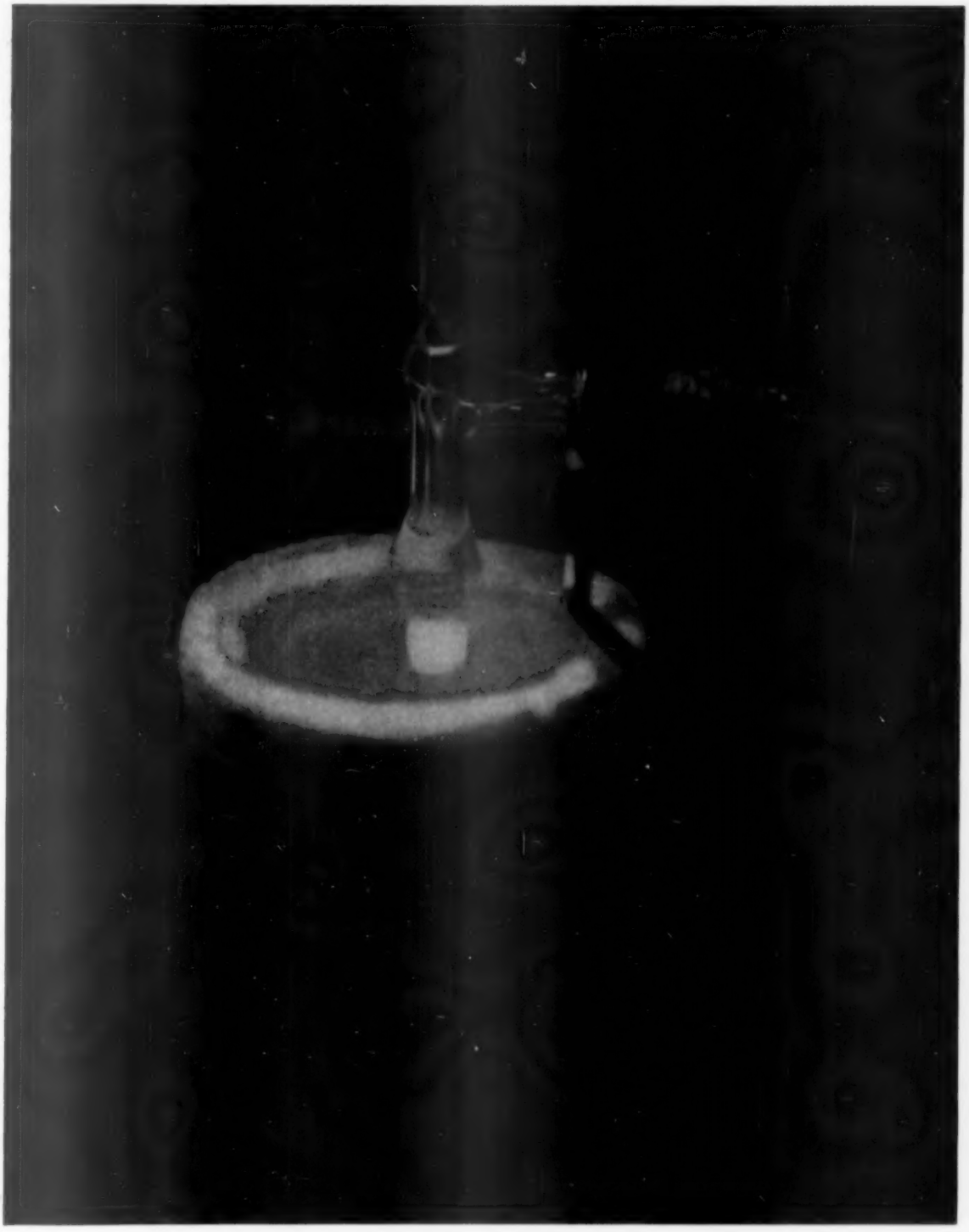


Super-heavy water—T_2O (51 mg) at −180° C, fluorescing under its own beta radiation at Oak Ridge National Laboratory

Producing Chemicals with Reactor Radiations

Use of fission fragments to irradiate basic gases in a reactor steps up ionization by a large factor and thus promises economic use of reactors for producing chemicals. Nitrogen fixation is an example

By P. HARTECK and S. DONDES
Chemistry Department, Rensselaer Polytechnic Institute, Troy, New York

TABLE 1—Some Results from Irradiation of Nitrogen-Oxygen Mixtures

Temperature (° C)	Thermal neutron flux (10^{12} n/cm²/sec)	Irradiation time (min)	5.0 mg UO_2 added	Filling pressure (atm)	Partial pressures NO_2 (mm)	Partial pressures N_2O (mm)	NO_2 (%)	G_{NO_2}
Filling, air								
−193 (liq. N_2 bath)	3.5	1,440	Yes	1 (600 mm)	95	1.16	15.8	E*
140	2.5	13,500	Yes	36	2,270	2,200	8.2	E
140	2.7	14,200	No	1	43	23	6.1	2.5
140	3.5	14,300	No	1/3	10.5	5	4.2	1.7
140	2.7	14,200	No	1/10	1.0	0.4	1.3	0.54
140	3.5	14,300	No	1/30	0.17	0.07	0.7	0.28
175	3.8	14,400	No	25	2,130	1,060	11.2	5.0
175	3.8	14,350	Yes	12.6	680	498	7.2	E
175	3.8	14,350	No	9.3	635	320	9	4.5
300	1.0	1,440	No	9.9	28	12	0.27	0.48
300	1.0	1,440	Yes	15.3	331	324	2.9	E
Filling, 50% nitrogen, 50% oxygen								
175	3.8	14,350	No	10.7	545	200	6.7	4.0
175	3.8	14,350	Yes	9.2	500	416	7.3	E

* In certain experimental holes in the pile, the samples had to remain for a period of about 10 days. In such cases, the nitrogen dioxide equilibrium concentration was almost reached with no added U^{235}. Thus the actual G_{NO_2} values for the build-up of nitrogen dioxide had to be calculated. With added U^{235} the NO_2 equilibrium was reached in a few days, and a high NO_2 concentration was built up; thus no G value could be calculated. E means equilibrium value. When U^{235} was absent, the $N^{14}(n,p)C^{14}$ reaction was considered in addition to pile radiation in calculating the G_{NO_2} values.

TO DATE, NUCLEAR REACTORS have been thought of primarily as sources of heat that can be used to generate electricity. Frequently the desired end product is chemical energy. Unfortunately the efficiency of going through the double conversion step—from heat to electrical energy to chemical energy—is low, about 10%. It would be attractive to go directly from fission energy to chemical energy. If an efficient nuclear-to-chemical-energy process can be found, not only can high over-all yields be obtained, but the costly intermediary, electricity, can be avoided.

With this objective we have devised a technique that uses fission-fragment ionization as well as the usual ionizing radiations and have irradiated carbon dioxide and nitrogen-oxygen mixtures. The latter experiments, which result in nitrogen fixation, are particularly pertinent because of the proposed expansion of nitrogen production to 3.5-million tons annually, a third of which may be in the form of nitrates (*1*). Our yields suggest the commercial usefulness of this process.

Usable Reactions

The best opportunity for direct transfer of nuclear to chemical energy

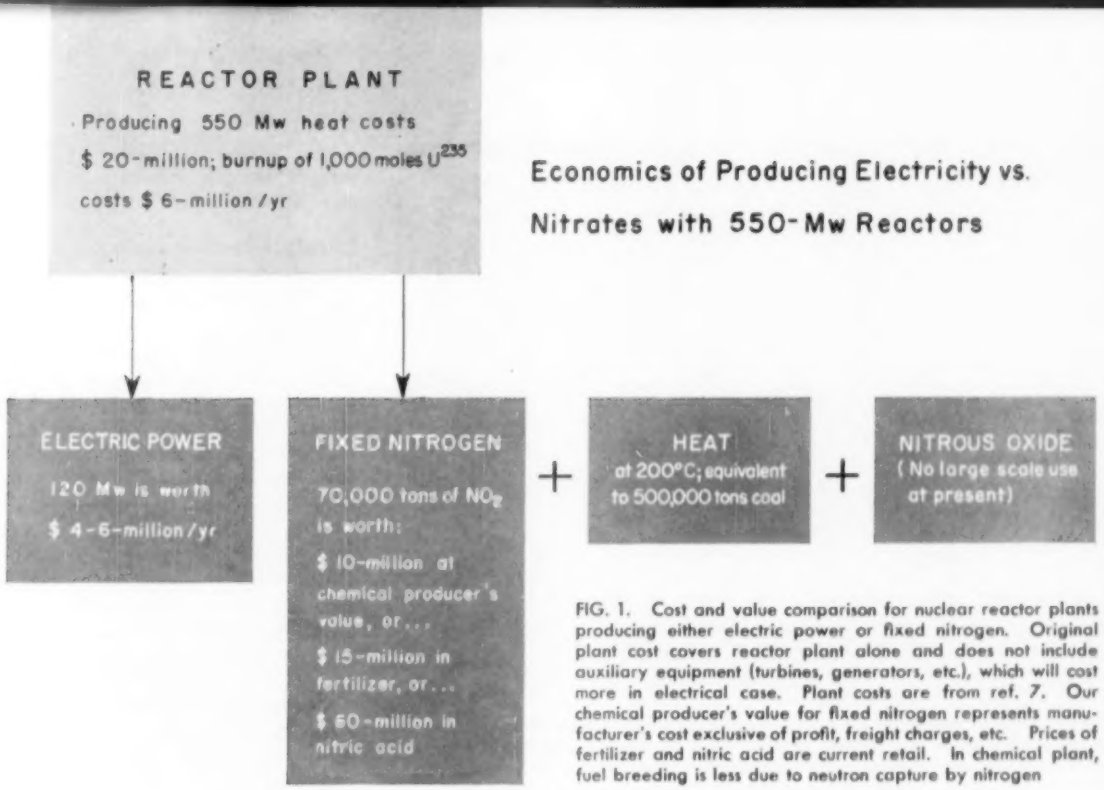

REACTOR PLANT
Producing 550 Mw heat costs $ 20-million; burnup of 1,000 moles U235 costs $ 6-million/yr
Economics of Producing Electricity vs. Nitrates with 550-Mw Reactors
ELECTRIC POWER
120 Mw is worth $ 4-6-million/yr
FIXED NITROGEN
70,000 tons of NO2 is worth:
$ 10-million at chemical producer's value, or...
$ 15-million in fertilizer, or...
$ 60-million in nitric acid
+
HEAT
at 200°C; equivalent to 500,000 tons coal
+
NITROUS OXIDE
(No large scale use at present)

FIG. 1. Cost and value comparison for nuclear reactor plants producing either electric power or fixed nitrogen. Original plant cost covers reactor plant alone and does not include auxiliary equipment (turbines, generators, etc.), which will cost more in electrical case. Plant costs are from ref. 7. Our chemical producer's value for fixed nitrogen represents manufacturer's cost exclusive of profit, freight charges, etc. Prices of fertilizer and nitric acid are current retail. In chemical plant, fuel breeding is less due to neutron capture by nitrogen

is probably with basic chemical gas reactions. The primary limitation is the thermal-neutron capture by the elements concerned. A high capture cross section means a costly process. An associated limitation is induced radioactivity, which can make the products worthless for most purposes. Finally, if the products formed have been in contact with the reactor fuel, they must be easily purified from the fission products (e.g., by distillation).

Fortunately, the most important basic gas reactions involve the elements carbon, hydrogen, nitrogen, and oxygen —all of which have small absorption cross sections for thermal neutrons. The induced radioactivity in these elements is of minor significance. Only C^{14} (5,580-yr half-life) is produced and that in small amounts.

Increasing ionization. Our experiments were made by adding enriched uranium (about 90% U^{235}) to a reaction vessel that subsequently was filled with gas and irradiated in the Brookhaven National Laboratory reactor. As little as 5 mg of UO_2 in a quartz vessel of 20-cm^3 capacity filled with 1-atm gas increased the ionizing radiation by a factor of 60 over its unperturbed value. Even here only 10% of the fission energy was available for ionization of the sample since most of the energy was absorbed in the uranium powder. Work is now under way to increase this figure to above 50%.

CO_2. We first irradiated carbon dioxide, which changes to carbon monoxide and oxygen when an inhibitor is added to stop the back reaction to carbon dioxide (*2*). Here 20–25% of the nuclear energy absorbed from the fission process is stored as chemical energy and can be released by simple burning. Also the carbon dioxide and oxygen can be separated and used in chemical synthesis.

NITROGEN FIXATION

We have also used nuclear energy for direct synthesis of a useful chemical. Nitrogen and oxygen were used to form nitrogen dioxide and nitrous oxide; their yields indicate commercial usefulness. Burnup of one mole of U^{235} will fix 70–80 tons of nitrogen as NO_2. There is additional value in N_2O.

Other workers have studied the reaction of oxygen and nitrogen to coat nitric-acid susceptible metals in the presence of water vapor in a reactor (*3*).

Samples of nitrogen-oxygen mixtures and nitrogen oxides were irradiated with and without U^{235} in the reaction vessels. With the U^{235} present the kinetic equilibrium between formation and decomposition of reactants and products could be obtained readily. Investigations involved radiation effects on mixtures of nitrogen and oxygen (1–99% nitrogen) at pressures of 0.01–50 atm and from −193 to 300° C. Sample results are shown in Table 1. Figure 2 shows the equilibrium mixtures as functions of concentration and temperature.

The results indicate that the most favorable conditions involve an 80%-nitrogen mixture (simply air), a pressure of over 10 atm (depending on strength of container), and a temperature of about 200° C. Experiments with oxygen concentrations above and below that of normal air produce smaller yields.

Using optimal temperature and mixture and the pressure available with our equipment, we filled a 100-cm^3 quartz vessel to 25 atm of dry air and irradiated it. The NO_2 could be condensed partly as nitrogen tetroxide liquid (N_2O_4, B.P. 21° C) by dipping the sealed vessel in cool water. We observed 0.1 cm^3 of nitrogen tetroxide.

By considering the amount of

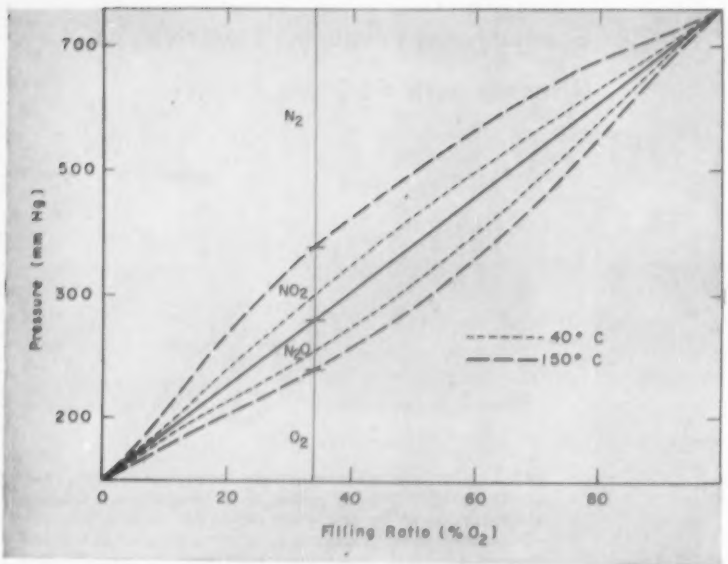


FIG. 2. Kinetic equilibrium diagram for nitrogen-oxygen system at 1 atmosphere. A vertical line at the proper filling ratio will be divided into segments that are proportional to the partial pressures of the four gaseous components of the equilibrium mixture. The sample line shows the equilibrium situation for 33% oxygen at 150° C

nitrous oxide also formed, we conclude that only a minor amount of the oxygen remains. From other more exact experiments the G value (number of molecules formed per 100 ev) obtained for nitrogen dioxide was 4–5 and for nitrous oxide 2–2.5 under favorable conditions. Under optimal conditions, G_{NO_2} may reach 6, and G_{N_2O} may reach 3. These results were determined by comparison with the nitrous-oxide dosimeter (*4*).

Mechanisms

The reactions important to the neutron-irradiation method of nitrogen fixation are listed in Table 2. Only the most important ones are included; the complex reactions with ozone, nitrogen pentoxide, etc., have been omitted since they appear to play no major role.

In a reactor facility especially designed for radiation chemistry, the nitrogen and oxygen molecules become ionized and decomposed by fission fragments in addition to the beta and gamma radiation, according to reactions 1–8. (This requires that U^{235} be used in a very finely dispersed form in direct contact with the gas.) Theory shows that in pure nitrogen 2.8 molecules can be ionized per 100 ev and 4–4.5 decomposed. Since the recombination of $N_2^+ + e^-$ may conceal additional dissociation, five nitrogen molecules may be dissociated, giving rise to 10 free atoms. If the atoms would react predominantly according to reaction 9, G_{NO_2} would be 10.

Undesirable Reactions

Unfortunately, there are undesirable reactions that cannot be avoided. At high total pressures reaction 11 will go very fast and the NO concentration will become small. Thus, the unfavorable effect of reaction 20 can almost be cancelled at high pressures. Reactions 25 and 26 are undesirable since NO becomes decomposed to a certain extent, and only a portion of the nitrogen atoms thus formed will reform NO by reactions 9 or 17, the other portion undergoing undesirable reactions.

It seems impossible to stop reactions 25 and 26 since nitric oxide has the lowest ionization potential, 9.5 volts, of all substances in the system; thus it will form NO^+ ions by exchange of charge with other positive ions at almost every collision. Nitrogen atoms may react according to reactions 9 and 17–20. Of these, reactions 9 and 17 are desirable, and 18–20 undesirable.

Thus the problem was to determine conditions under which the G value for nitrogen-dioxide formation becomes large. We have said that a high pressure is desirable. Next, a consideration must be given to temperature.

Effect of Temperature

Low temperatures (20–100° C) are not favorable since reaction 20 has almost no heat of activation and therefore is especially important at low temperatures. Reactions 17–19 have a small heat of activation and reaction 9 has a heat of activation higher than the reactions 17–20. An increase in temperature decreases the effect of a heat of activation. Of reactions 17–19, 17 is desirable, and 18 and 19 undesirable. From reaction 18, a certain amount of N_2O is produced in parallel with the formation of NO_2 (*5*). This cannot be avoided, but it is unfavorable since it consumes one fixed nitrogen atom and one free one.

Fortunately, reaction 19 is small compared with reaction 17. Thus it would seem that the temperature should be raised to the point where the most desirable reaction, 9, becomes

TABLE 2—Reactions Available Among N, O, and Combinations

1. $N_2 \xrightarrow{\text{(rad)}} N_2^+ + e^-$
2. $N_2 \xrightarrow{\text{(rad)}} N_2^*$
3. $N_2^* \rightarrow N + N$
4. $N_2^+ + e^- \rightarrow N + N$ or $N_2 + \gamma$
5. $O_2 \xrightarrow{\text{(rad)}} O_2^+ + e^-$
6. $O_2 \xrightarrow{\text{(rad)}} O_2^*$
7. $O_2^* \rightarrow O + O$
8. $O_2^+ + e^- \rightarrow O + O$ or $O_2 + \gamma$
9. $N + O_2 \rightarrow NO + O$
10. $NO_2 + O \rightarrow NO + O_2$
11. $2NO + O_2 \rightarrow 2NO_2$
12. $2NO_2 \rightleftarrows N_2O_4$
13. $NO_2 \xrightarrow{\text{(rad)}} NO_2^+ + e^-$
14. $NO_2 \xrightarrow{\text{(rad)}} NO_2^*$
15. NO_2^* } $\rightarrow$ { $NO + O$
16. $NO_2^+ + e^-$ } $\rightarrow$ { $N + 2O$
17. $NO_2 + N \rightarrow 2NO$
18. $NO_2 + N \rightarrow N_2O + O$
19. $NO_2 + N \rightarrow N_2 + 2O$
20. $NO + N \rightarrow N_2 + O$
21. $N_2O \xrightarrow{\text{(rad)}} N_2O^+ + e^-$
22. $N_2O \xrightarrow{\text{(rad)}} N_2O^*$
23. N_2O^* } $\rightarrow$ { $N_2 + O$
24. $N_2O^+ + e^-$ } $\rightarrow$ { $2N + O$
25. $NO + M^+ = NO^+ + M$
26. $NO^+ + e^- = N + O$ or $NO + \gamma$
27. $2\ NO_2 \rightleftarrows 2NO + O_2$

dominant. However, at temperatures above 250° C, the thermal-equilibrium reaction, 27, is noticeably pushed to the right, and the NO, which is now in thermal equilibrium, enhances the undesirable reactions 20, 25, 26. Thus an optimal temperature region exists from 175–225° C.

In avoiding reaction 20 and decreasing the influence of reactions 25 and 26, reactions 17 and 9 should produce a G_{NO_2} value of 4–5 in an original mixture of 80% nitrogen and 20% oxygen. The reason why nitrogen fixation by reactor irradiation has been disregarded to date may be that experiments were normally conducted at room temperature and at atmospheric or lower pressures where the conditions are not favorable.

ECONOMICS

An examination of the economics of nitrogen fixation by reactor irradiation consists primarily of a comparison of the value of the product formed (NO_2) with the value of the fuel burned up and with the value of electric power that would be produced with the same amount of fuel.

The U^{235} fission releases about 170 Mev of locally absorbed energy (Table 3). The value of G_{NO_2} under optimal conditions may be 6 if we disregard the stopping power of the fuel element. The fission energy could produce a maximum of 10.2×10^6 moles of nitrogen dioxide per mole of U^{235}. A more realistic estimate can be made if we assume that about 30–40% of the fission energy is absorbed in the dispersed U^{235} alloy and that the G value for the nitrogen fixation is 4.5–5. This means that the over-all efficiency is at least 50%, which should be readily obtainable in practice.

TABLE 3—The Fission-Energy Distribution

Kinetic energy of fission fragments	162 Mev
Beta radiation	5
Decay gamma radiation	5
Instantaneous gamma radiation	6
Neutrinos	11
Fission neutrons	6
Total	195
Energy that escapes*	−25
Locally absorbed	170

* Neutrinos escape entirely, and gamma-rays and neutron energy are only slightly absorbed.

Product vs. Cost

Under these conditions, 5×10^6 moles of NO_2 per mole of U^{235} will be produced, which is equivalent to 258 short tons. For 38° Baumé nitric acid (42.3% NO_2), this would be 610 short tons. With the present price of technical nitric acid (38° Baumé) of $125 per ton (*6*), the value of the nitric acid becomes $76,000, which may be compared with the present price of one mole of U^{235} when it is in a 20% enriched form, $5,875 (NU, Sept. 1955, p. 110).

To consider only the value of the nitric acid is probably not realistic enough. However the value for nitrates (even in fertilizers) compares favorably since if we consider a chemical producer's price of fixed nitrogen in nitrates as $150 per ton of nitrogen content, this gives for the 70 tons of fixed nitrogen a value of $10,500 as compared with $5,875 for a mole of U^{235}.

Byproducts

The same mole of U^{235} producing the NO_2 will also produce 110 tons of N_2O under the same conditions. Its value as byproduct is difficult to estimate since at the present time there is no market for such huge quantities of N_2O. But one may be found in the future. Other products that have not been assigned any dollar values are nuclear fuel produced from fertile material and heat.

WHAT KIND OF REACTOR?

The economics suggest a reactor constructed primarily for the fixation of nitrogen. Since the process operates at about 200° C, dual-purpose reactors may also be considered where power or at least steam is produced simultaneously with the nitrogen oxides. In any case thought must be given to the fact that normal nitrogen has an absorption cross section of 1.78 barns for thermal neutrons.

Because of the large neutron absorption by nitrogen additional reactivity must be built into the pile, and it will be necessary to keep the pressure or concentration of the nitrogen constant and use special controls so as not to affect the criticality of the reactor.

Our results in static systems indicate that a flowing system, as would be used in a commercial plant, should enhance the production of NO_2 and decrease the amount of N_2O since reaction 18 would be decreased when the nitrogen dioxide is removed from the mixture.

The capabilities of a plant producing NO_2 by fixing nitrogen through nuclear energy may be added readily to existing plant facilities making nitrates and fertilizers.

* * *

The authors wish to thank M. Fox, R. Powell, J. Floyd and F. Reeve of the reactor department at Brookhaven National Laboratory for their excellent advice and cooperation in this work. The work was supported by the USAEC.

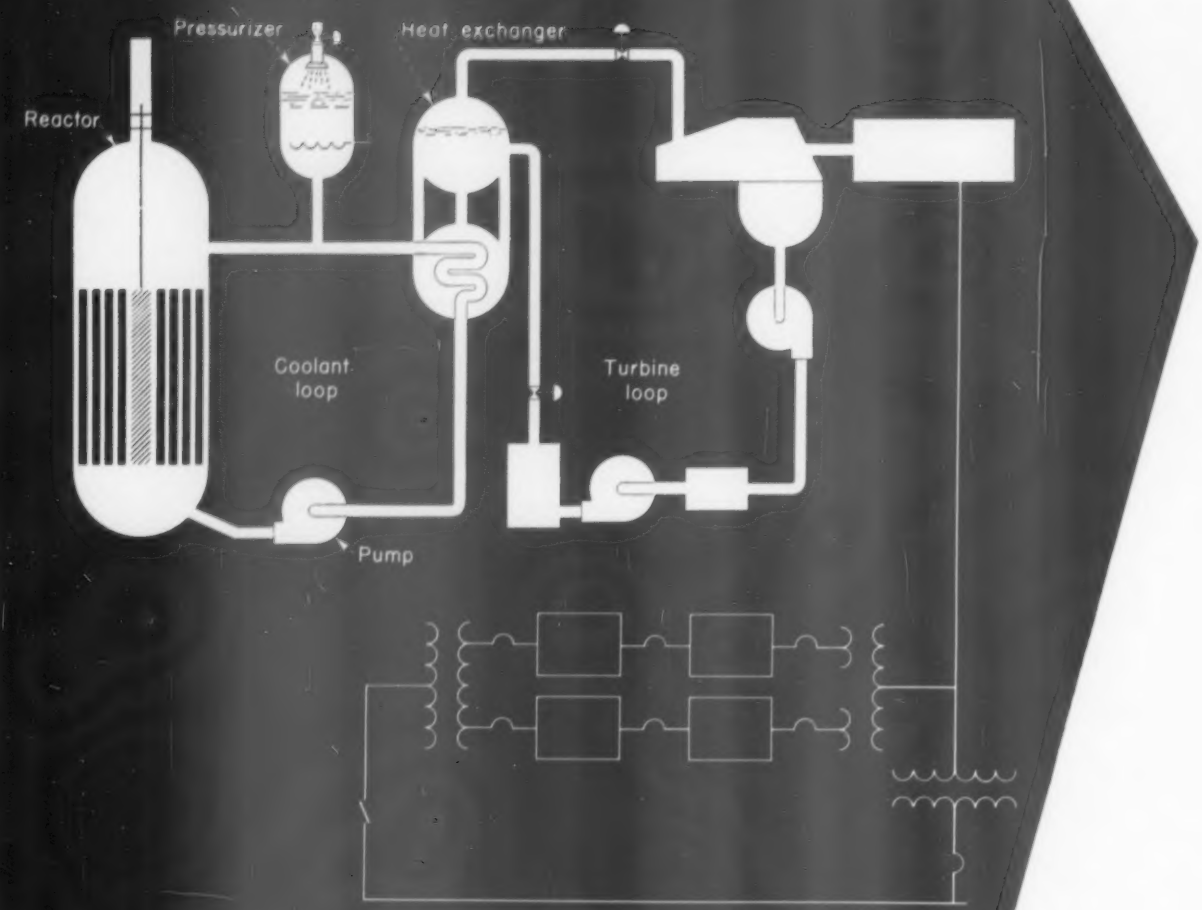
Induced Radioactivity

The induced radioactivity is not negligible, for about 5 kg of C^{14} per year will be produced by a burnup of 1,000 moles of U^{235}—$N^{14}(n,p)C^{14}$. It will appear as carbon dioxide and carbon monoxide in the system. Since the nitrogen dioxide is stripped in cool water, it will be free of these two gases, and the induced radioactivity in this product can be neglected.

The removal of the C^{14} can be effected as carbon dioxide by passing the gas mixture through calcium hydroxide solution. Carbon monoxide and residual oxygen can be combined over a catalyst and removed by passage through the same calcium hydroxide solution or another. Since calcium carbonate is insoluble in water, it can be buried at sea, as is presently done with fission products. The C^{14} may have some usefulness, as in tagging compounds.

BIBLIOGRAPHY

1. *Chem. Eng. News* **33,** 5571 (1955)
2. P. Harteck, S. Dondes, *J. Chem. Phys.* **23,** 902 (1955); Part II (to be published)
3. W. Primak, L. H. Fuchs, NUCLEONICS **13,** No. 3, 39 (1955)
4. P. Harteck, S. Dondes, NUCLEONICS **14,** No. 3, 66 (1956)
5. P. Harteck, S. Dondes, *J. Chem. Phys.* **23,** 953 (1954)
6. *Chem. Eng. News* **33,** 5599 (1955)
7. "A Growth Survey of the Atomic Industry 1955–1965" (Atomic Industrial Forum, Inc., New York, 1955)
8. S. Glasstone, M. C. Edlund, "The Elements of Nuclear Reactor Theory" (D. Van Nostrand Co., Inc., New York, 1952)



COLD-STATION STARTUP (after extended shutdown). Initially, coolant system is at <150 psig, turbine-generator is on "motor slow roll", auxiliary systems are in service or ready. Then coolant circulation is started and coolant is brought slowly to temperature and pressure with pressurizer and then by energizing control rods

COOLANT SYSTEM (only one of four loops shown). Coolant circulates in closed loop through reactor and heat-exchanger section of steam generator. Pressurizer, with electric immersion heaters, maintains coolant pressure to prevent boiling in reactor core. Spray nozzle, supplied from coolant-pump discharge, at top of pressurizer assists in controlling load-change surges. Auxiliary systems (not shown): demineralizer purification system, charging system, discharge and vent system, and waste-disposal system

TURBINE-PLANT STARTUP. During reactor-plant warmup, turbine plant is put in operation. Condensate system is put in service. At 75 psig, turbine is put in "steam slow roll." After checking for rubs and shaft eccentricity, speed is increased to 1,800 rpm. Generator is energized

TURBINE-GENERATOR SYSTEM. Components are conventional except that turbine uses saturated steam, requiring moisture separator and Stellite and stainless steel in turbine to minimize erosion

FINAL STEPS. Turbine-generator is set up for normal operation. Boiler feedwater is placed on automatic control. With coolant at 525° F, rod controls are put on automatic

STATION-SERVICE SYSTEM. Electric plant is conventional except for station service. For greater flexibility and stability for reactor-plant auxiliaries, four 2,400-volt buses are provided instead of normal two. This is accomplished with twin secondary windings on station-service transformers. One transformer is fed from generator leads and other from 138-kv system network

Getting PWR on the Line

With the Shippingport power station scheduled to go critical in June, 1957, operating plans are now being firmed up. Duquesne Light Co.'s approach to two aspects of operation—cold-station startup and personnel—are described here

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1—Startup Procedure*

THE SHIPPINGPORT power station will be similar to conventional stations in that several different startup procedures will be used. These procedures will differ mainly in the starting point, with the final steps of startup being very similar.

The specific procedure to be followed in any one startup will depend on the station conditions existing at the time of the startup, which will in turn depend on the purpose and length of the previous out-age. The procedure to be presented in this paper is the cold-station startup procedure, which will be the one of longest duration, but will be used only after an extended shutdown of the reactor.

Initial Station Conditions

For this particular startup, it is assumed that station conditions are as follows:

1. All station service buses are energized from the 138-kv network.

2. The reactor coolant and associated systems are completely filled with water at ambient temperature and at a pressure less than 150 psig. The water is of the required purity except for oxygen content.

3. The purification system is isolated and the pressurizer spray line is open.

4. The precritical check out of reactor controls and instrumentation is completed.

5. The turbine-generator is on "motor slow roll." The generator shell is filled with hydrogen.

6. The condensate and boiler-feed systems are set up for operation with drum level slightly below normal and steam lead vents and drains open.

7. All reactor and turbine-generator plant auxiliary systems are either in service or available for service.

Coolant-System Warm-Up

With these conditions established, the first steps in the procedure are the chemical treatment of the reactor coolant for oxygen removal and the initiation of the reactor coolant system warm-up.

In the following procedure, several minor steps have been omitted for simplicity.

1. The reactor coolant pumps are started at high speed, and coolant is circulated through the loops and the pressurizer spray circuit.

2. The system is pressurized to 400 psig by the charging-system pumps. The pressurizer heaters are energized to assist the reactor-coolant pumps in raising the coolant temperature.

3. Reactor coolant is sampled and analyzed to determine its oxygen content. The required amount of hydrazine is added to the system for oxygen scavenging.

4. The coolant is then circulated for about 4 hr to permit the hydrazine-oxygen reaction to take place. During this period, the coolant pressure is maintained between 400 and 600 psig by discharging water as required. The coolant temperature is maintained between 190° F and 200° F by de-energizing the pressurizer heaters and cycling the coolant pumps as required.

5. When oxygen concentration has been reduced to the desired level, the pressurizer spray-line valve is closed and all heaters are energized. The pressurizer now assumes its true function—that of pressurizing the reactor coolant to prevent boiling in the core. From this point on, pressurizer water temperature should be at least 100° F but not more than 200° F higher than the coincident coolant temperature. The pressurizer temperature rise is limited to a maximum uniform rate of 100° F/hr.

6. The purification system is placed in service. This system was isolated previously to prevent the demineralizers from removing the hydrazine from solution.

7. Hydrogen is added to the reactor coolant so that free hydrogen is available for scavenging the oxygen released,

* Parts 1 and 2 of this article are based on papers presented by L. R. Love and G. M. Oldham, respectively, at the Tenth Annual Mechanical Engineering Conference on Nuclear Power Plants, Pittsburgh, Pa., May 1, 1956.

due to water decomposition, after the reactor is placed in service.

8. When the pressurizer temperature reaches 400° F, a steam bubble is formed in the pressurizer by reducing coolant pressure to approximately 200 psig. During subsequent steps, the pressurizer level is maintained within the prescribed limits by discharging or adding water as required.

9. The reactor control-rod system is then energized and rod withdrawal begun to continue the warm-up of reactor coolant. During rod withdrawal, the neutron level and the level-change-rate instruments are closely observed to insure that the level-change rate is below the specified values. As the point of predicted criticality is approached, continuous rod withdrawal is stopped, and the rods are withdrawn in small steps until criticality is reached. Protective devices are provided to limit the speed of approach to criticality. If the level-change rate should exceed a predetermined value, rod motion will be stopped automatically.

10. When the reactor is critical, the control-rod position is adjusted to produce a power level equivalent to 1–2% of full power, or as required to heat reactor coolant at a rate of 100° F per hour. To maintain this power level, the rods must be further withdrawn at intervals to compensate for the negative temperature coefficient, which will reduce power level as temperatures increase unless reactivity is added.

11. The pressurizer heaters and spray-valve control are then placed on automatic.

Turbine-Plant Start-Up

While proceeding with the warmup of the reactor plant, the turbine-generator plant will be placed in service as follows:

1. The condenser circulating water flow is established, and the condensate system is placed in service, circulating water from the condenser hotwell through the air-ejector condenser and other heat exchangers back to the hotwell.

2. The turbine glands are sealed, and the air ejector is placed in service to evacuate the condenser.

3. The drum vents are closed when pressure reaches approximately 20 psig, and the free drains on the steam leads and the header are checked to insure that they are free of water.

4. The turbine high-pressure auxiliary oil pump is started, and the various drains on the turbine are opened in preparation for placing the turbine on "steam slow roll."

5. When steam pressure is approximately 75 psig (reactor-coolant temperature 300° F), and the condenser vacuum is at least 10 in. of Hg, the throttle valves are opened, and steam is admitted to the turbine to place it on "steam slow roll." When steam is admitted to the turbine, the free drains on the steam leads and the header are closed.

6. If the turbine is free of rubs, the speed is increased to approximately 150 rpm, and the shaft eccentricity is checked.

7. If the shaft is true (eccentricity less than 0.001 inches), the turbine speed will be increased to 1,800 rpm at a uniform rate in approximately 25 min.

8. The boiler feed system is placed in service when required, and the drum level is controlled manually.

9. As the turbine speed approaches 1,800 rpm, the governor controls are observed to insure that speed is properly controlled.

10. The overspeed trip mechanism is checked by increasing turbine speed slowly to the trip point, and the throttle valves are immediately reopened.

11. Excitation voltage is applied to the generator field and is adjusted as necessary to match generator voltage with system voltage.

12. The generator is synchronized and loaded to 5–10 Mw, and voltage control is placed on automatic.

13. Half of the station service load is switched to the generator-lead station service transformer.

Final Steps

During this period, the reactor plant warmup will have continued at a rate of 100° F per hour, and the reactor coolant temperature will have risen to approximately 400° F. During the loading of the station and the completion of the reactor coolant system warmup, the following steps are taken.

1. The turbine-generator and auxiliaries are set up for normal running operation, and the generator is loaded at specified rates in accordance with system requirements.

2. The boiler-feedwater system is placed on automatic control when flow conditions permit.

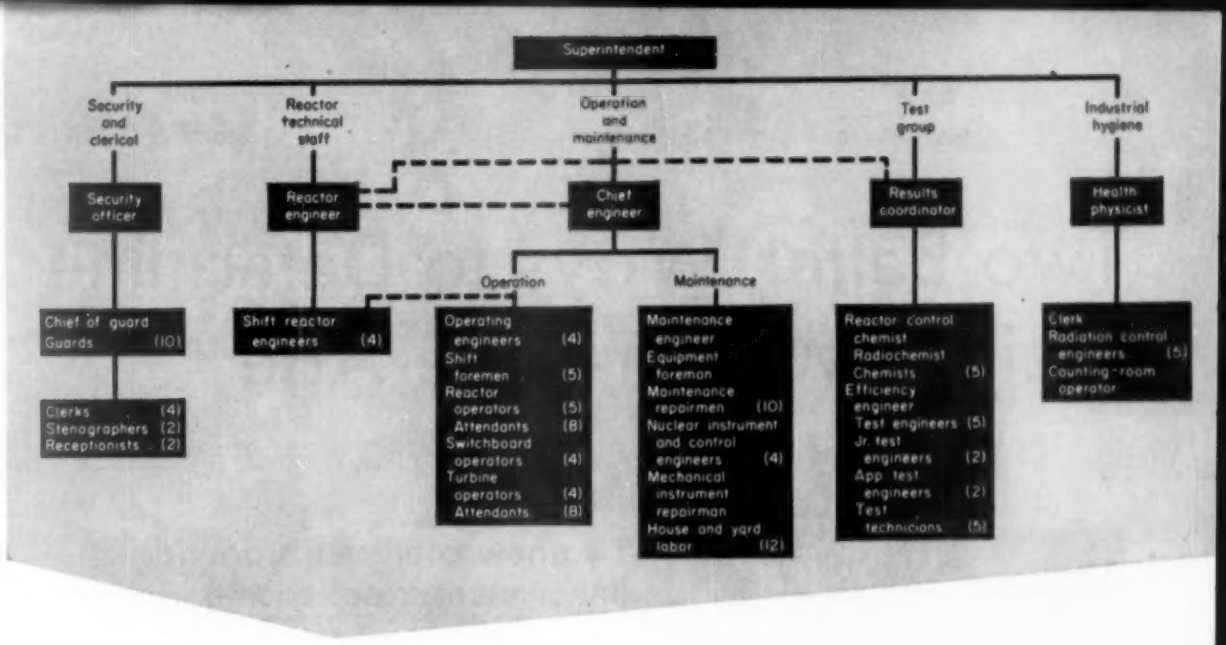
3. When average reactor coolant temperature reaches 525° F, the rod control system is placed on automatic control.

4. The reactor coolant is sampled and analyzed for oxygen content, and hydrogen is added as required.

The Station is now capable of accepting its share of load swings as required for system regulation (determined by consumer demand). To be specific, it will be required to follow daily system load changes at an average rate of 3 Mw per minute, and to accept load swings of 20 Mw maximum at a rate of 24 Mw per minute. It must also handle a proportional part of the load swings imposed on the various stations by casualties on the system.

The output of the reactor will follow all but the largest load changes without immediate control-rod movement, due to the negative temperature coefficient of reactivity inherent in the core, which permits it to produce only that power which is taken from it. However, subsequent changes in control-rod position are required to maintain average temperature constant due to the change in xenon concentration in the core following load changes. Xenon, which is a fission product, absorbs neutrons. Its change in concentration with power level causes changes in reactivity.

With the type of startup described here, the time required to reach the normal operating range (20–100% of full power) from a cold condition would be approximately 8 hr. This is considerably longer than the $5\frac{1}{2}$ hr required for a similar startup of a conventional station of this size, but as was mentioned earlier, this startup will be used infrequently. The most frequent startup is one where the reactor coolant and associated systems have been maintained at or near operating temperature during the shutdown. In a startup from this condition, the hydrazine treatment would not be necessary, and the delay introduced by the requirement for heating reactor coolant would be eliminated. This would reduce the time required for startup to approximately $1\frac{1}{2}$ hr as compared to $2\frac{1}{2}$ hr required for the hot startup of a conventional station. As these comparisons of startup times indicate, the reactor plant will be as flexible and, in some instances, more flexible than a coal-fired boiler plant. Also, the startup procedure shows that the actual mechanics of reactor-plant operation are no more difficult than conventional plant operation.



2—Staffing the Plant

THE STAFFING PROGRAM for the Shippingport nuclear power station is more difficult than for conventional steam stations because of the lack of precedents and the lack of personnel with nuclear training within the company. Use of the station as a test facility complicates the problem.

To fill out the staff of the station, 126 people are considered necessary. Of these, 37 will be technically trained. Several of the factors leading to these high numbers are: (a) The station is the first of its kind, involving new techniques. (b) More men are necessitated by the extensive test program and by the emphasis on health and security. (c) A pool of technical manpower must be maintained to compensate for the normal turnover; this may become critical as the number of nuclear power stations grows.

Training

Except where recent college graduates are used and where individuals with specialized training, e.g., radiochemists, are required, all personnel probably can be obtained from within the company.

In addition to on-the-job training, all technical and some nontechnical men are given practical training in reactor-station operation to provide background for their own jobs and to instill an appreciation of the hazards involved. Each technical man also receives theoretical nuclear training, and all personnel receive general training in health physics and security.

Most training is provided at the Westinghouse-operated Naval Reactor Facility at Arco, Idaho. At the completion of this course, about fifty men will have trained for an average of four months. Some will also be trained at the Bettis Plant in Pittsburgh.

Organization

The organization consists of five functional groups (see chart), each headed by a supervisor reporting to the superintendent. This type of organization was selected because it satisfies the program objectives of operation and test development.

Operation and maintenance group is responsible for the entire plant.

Operating staff is larger than that normally found in a single-unit station by the addition of the shift reactor engineer and two attendants. The additional attendant in the turbine plant is provided because certain items requiring local operation and routine attention, such as screenhouse equipment, are remotely located. Although there are fewer items of this nature in the reactor plant, two attendants are provided since the local operations may be more time consuming due to the use of a change-room facility, which prevents the spread of radioactive contamination.

Maintenance staff is larger than in conventional station because of the high degree of station cleanliness necessary. More repairmen are required since radioactivity levels could limit the amount of time a man can work on reactor-plant equipment. Relative inaccessibility of equipment and need for absolute leaktightness add to manpower requirements. Four instrument and control engineers are necessitated by the complicated reactor-plant instrumentation and control and the extensive test program.

Test group performs all tests and assists in evaluating new methods of operation and control. Its size is dictated by the test program. The chemical group is much larger than ordinarily due to the many unknowns in reactor-plant chemistry.

Technical staff provides technical assistance to the operating, maintenance, and test groups insofar as the reactor plant is concerned and is responsible for reactor-plant safety.

Industrial hygiene group performs routine radiation surveys of personnel, work areas, and adjacent off-site areas. This group is peculiar to a reactor plant.

Security and clerical group is responsible for security of classified documents and fissionable material.

* * *

This article is based on papers presented at the Tenth Annual Mechanical Engineering Conference on Nuclear Power Plants, Pittsburgh, Pa., May 1, 1956.

Two Better Ways to Determine Geiger-Mueller-Tube Age

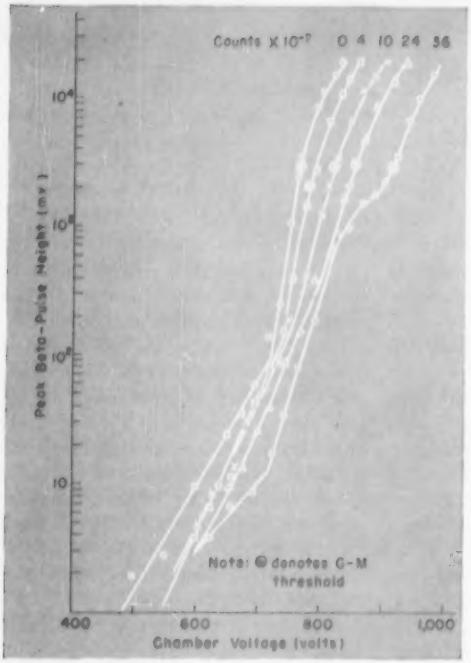


FIG. 1. Beta-pulse-height characteristic curve

Two new coefficients provide a linear measure of counter age:

1 Threshold Coefficient—the change in threshold voltage per tenfold increase in counting rate

2 Amplitude Coefficient—absolute value of exponent in the power law expressing the relation between pulse height and counting rate at fixed voltage

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THE TWO NEW METHODS discussed here afford a simpler way to measure counter age than the increase in slope and final disappearance of the counter plateau used heretofore (*1–8*). The determination of such plateau curves takes time, must be done with carefully controlled geometry if results at different times are to be compared, and can be damaging to the counter if operation is prolonged at high overvoltages.

* Under contract to the U. S. Atomic Energy Commission.

Beta-Pulse-Height Methods

At first we used a more involved method, which will be described here because it illustrates the experimental techniques used and reveals how we were led to the new amplitude and threshold coefficients.

The beta-pulse-height characteristic is a plot of tube voltage versus the maximum pulse height observed from a counter exposed to a beta ray source. This maximum pulse height corresponds to the maximum ionization produced in the counter by the beta rays. Beta emitters of different energy give different maximum ionizations and thus produce curves of different relative shape in the region of limited proportionality. However, for a given source and a given arrangement of source and counter, one gets a particular curve that can be examined for changes with age.

Procedure. A uranium source was arranged to give ~1,200 cpm. The counter was coupled to a cathode-follower preamplifier and the pulses ob-

Threshold Coefficient

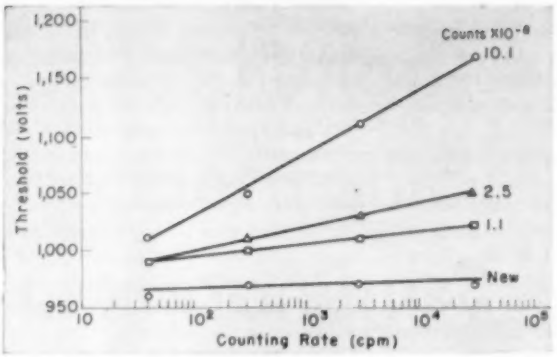


FIG. 2. Threshold voltage vs. counting rate

Amplitude Coefficient

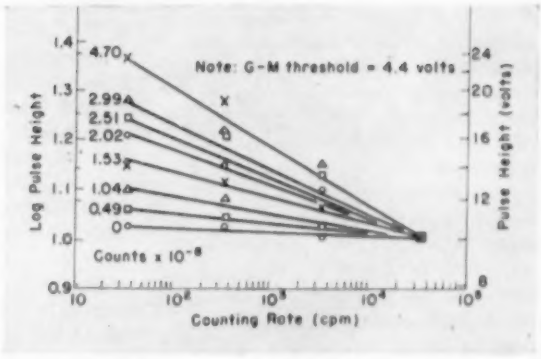


FIG. 3. Threshold coefficient vs. total counts

Since the pulse height at the Geiger threshold does not vary with age it is an especially valuable reference point for age studies.

The voltage necessary to keep the counter at the Geiger threshold was measured as a function of age and of counting rate. This threshold voltage was found to increase linearly with the logarithm of the counting rate, the rate of increase being greater for older counters. Figure 2 shows the result for a mica-window counter; other counters gave similar results.

It was decided to call the change in threshold voltage (in volts) per factor of ten increase in counting rate the "threshold coefficient." The threshold coefficient for the mica-window counter is shown in Fig. 3.

Advantages. *Threshold coefficient is proportional to the total number of counts and is essentially zero for a new tube. This avoids one of the difficulties in the use of the beta-pulse-height characteristic, since a single measurement of the threshold coefficient at any age is sufficient to fix the age. A measurement of the threshold coefficient of the new tube is not necessary. Furthermore, the effects of temperature are eliminated by operating at the fixed pulse height of the Geiger threshold. The effect of temperature change is to shift the beta-pulse-height characteristic to higher or lower voltages; thus the threshold voltage will be changed but the voltage difference required to obtain the threshold coefficient will remain constant. A precision voltmeter is still needed to measure the threshold coefficient, but the measurements are not very difficult nor time consuming.*

Another way of studying changes in pulse height with counting rate is to investigate the variations at a fixed counter voltage. A certain pulse height, possibly the pulse height at Geiger threshold but preferably one somewhat higher, is picked as a reference. The counter is subjected to the highest counting rate contemplated and the counter voltage adjusted so that this reference pulse height is obtained. With counter voltage fixed, pulse heights are measured as counting rate is decreased to background.

Figure 4 shows the results for a particular counter; similar results were obtained for the other counters. The pulse heights were found to decrease as a power of the counting rate with the exponent in the power law increasing with age.

The absolute value of the exponent in the power law is called the "amplitude coefficient." The amplitude coefficient for the tube used for Fig. 4 is plotted vs. total counts in Fig. 5.

Advantages. *The amplitude coefficient is approximately zero for the new tube and increases linearly with age; thus, it has the same advantage as the threshold coefficient over the beta-pulse-height characteristic curve. It avoids temperature effects by not involving counter voltages. For the same reason, a precision voltmeter is not required.*

The change in pulse height with counting rate did not occur instantaneously but required a finite time (just how much time depended upon whether the counting rate was increasing or decreasing). For a mica-window counter whose window was coated with aluminum by evaporation, the change took 30 sec when rate increased and 60 sec when decreased.

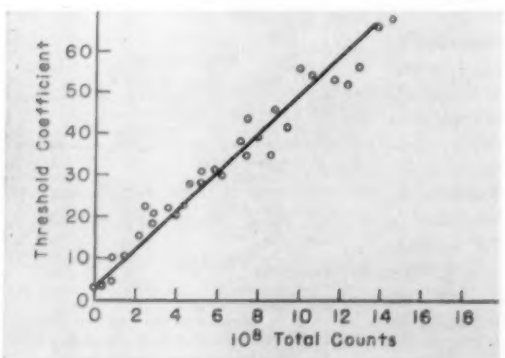


FIG. 4. Pulse height vs. counting rate

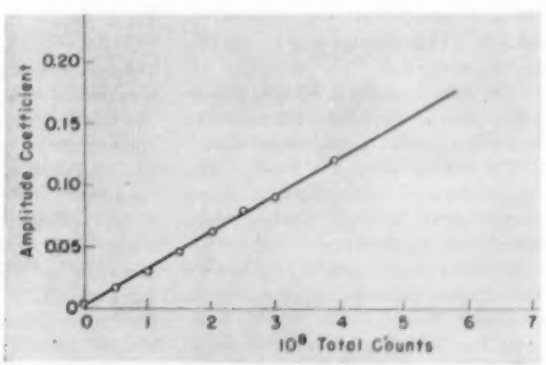


FIG. 5. Amplitude coefficient vs. total counts

What Is Counter Age?

As a G-M counter counts, or even after periods in which it has not counted, changes occur: pulse height decreases, threshold voltage increases, plateau length and slope change, spurious counts arise, etc. (1–3). These changes are spoken of anthropomorphically as "aging" of the counter during its "life." Aside from mechanical damage, the chief causes of aging in self-quenching counters have been found to be changes in the composition of the counting gas (4–6) and deposition of breakdown products from the counting gas on the electrodes (4–5).

served on an oscilloscope. An 18-megohm signal resistor produced pulses easily observable even on a slow oscilloscope. Counter voltages were measured with an electrostatic voltmeter. The same source was used for aging of the counters at 20,000–40,000-cpm counting rates. Tube voltages were such as to produce a maximum pulse height two to three times that at Geiger threshold. All counters were studied for at least 10^8 total counts; some were investigated until some type of failure occurred. Beta-pulse-height characteristics were obtained for four different types of commercially available cylindrical counters and one type of mica-window counter. All counters were of the low-pressure self-quenching type.

Figure 1 shows the beta-pulse-height characteristic curves for a particular counter. The total number of counts the counter had made is shown on each curve. With increasing number of total counts the curve moved toward higher voltages. This fits the common observation that higher voltages are required to operate old tubes. In the Geiger region the voltage shift was proportional to the total number of counts. This was not true in the proportional regions.

The pulse height at the Geiger threshold remained constant with age—this has proved to be a very useful fact.

The voltage shift of the beta-pulse-height characteristic could be used as a measure of the tube age; however, there are several disadvantages:

1. Considerable time is required for the measurement of enough points for a curve.
2. The curves were found to shift with temperature by an amount comparable with the shift with age.
3. A precision voltmeter is needed for the voltage measurement.
4. The voltage shift gives only a relative measurement (i.e., the position of the characteristic curve for a new counter is not known without a separate measurement).
5. It was found that the curves were rate-dependent.

The first beta-pulse-height characteristics were determined without controlling the counting rate other than to keep it within such a range that enough pulses were displayed on the oscilloscope at any one time to make visual observation of the maximum pulse height convenient. At first this made no difference. However, as the counter aged, at any given voltage in the Geiger region the pulse heights on background were higher than those found during the measurements; this effect became more pronounced as the tube aged. After this observation, a convenient counting rate was selected and used during the remainder of the measurements.

This variation in pulse height with counting rate as a function of counter age led to the work on threshold and amplitude coefficients discussed on p. 31.

Twin-Tube Experiment

The aging of Geiger counters has been attributed to such things as degeneration of the quench gas, pitting of the anode, and the formation of organic deposits inside the counter (*4–5*). An experiment was performed to determine which of these might be the main cause of the effects described above. Two thin-wall glass counter shells were joined with a common filling tube. The two counters shared the counting gas but were electrically separate. The filling gas was 9 cm Hg argon and 1 cm Hg alcohol.

Voltage was applied to only one of the counters and it was aged in the manner described above. At intervals the threshold coefficient and amplitude coefficients of both tubes were measured. The counter that had actually been aged showed threshold and amplitude coefficients similar to those of other aged counters. The counter that had not been aged did not show any measurable coefficients. However, the tubes showed equal increases in Geiger threshold voltage with age.

Since the changes in threshold voltage occurred in both tubes, they must be due to changes in the counting gas. Continued operation of a counter results in breakdown of the quenching gas (*4*) with consequent rise in pressure and increase in operating voltages. Since only the aged tube showed thresholds and amplitude coefficients, these effects must be due to changes in the electrodes. As the quenching gas is decomposed, organic deposits are formed on the electrodes (*5*). These are nonconducting and will become charged (*9, 10*) in a sense to reduce the overvoltage on the counter with consequent reduction in pulse height. The equilibrium charge on these deposits will depend on the counting rate; this will lead to the effects described by the threshold and amplitude coefficients.

Discussion

The threshold and amplitude coefficients or suitable modifications of them provide convenient tests of counter age for use in age investigations or routine counter control. An oscilloscope is the only instrument required for their measurement that is not already available when using counters. The measurements are simple and require little time.

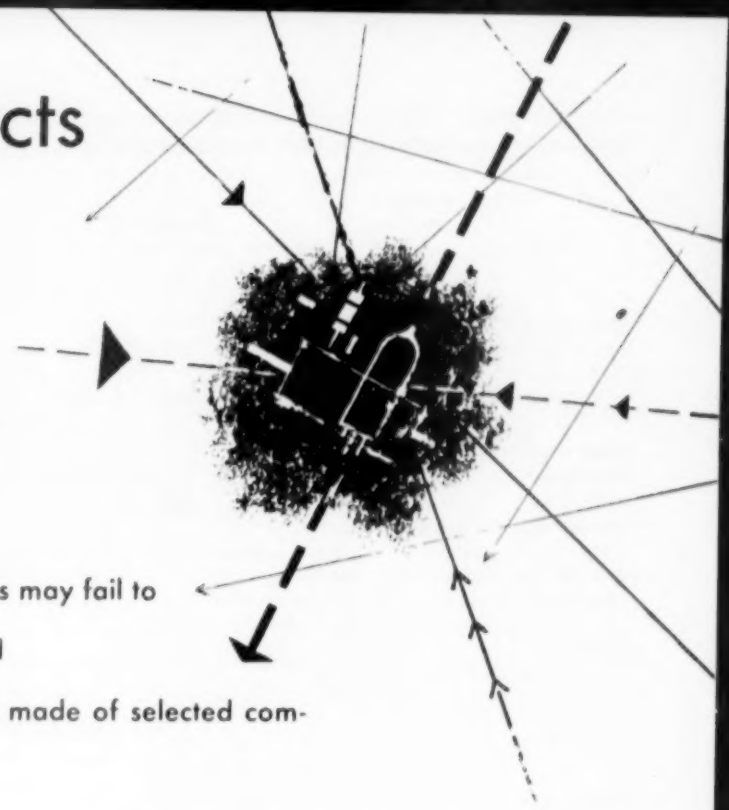
Further simplification is possible if relative measurements only are desired, e.g. instead of measuring the amplitude coefficient one can use the logarithm of the ratio of the pulse heights at any two convenient counting rates. The fact that the coefficients are zero for the new tubes provides a fixed reference point that other methods of age study, beta-pulse-height characteristics or plateau changes, do not have.

We have found these coefficients valuable in studies of the effects of capacitative loading and counting rate on counter aging and in control of mica-window counting sets over long intervals of time.

BIBLIOGRAPHY

1. S. A. Korff, "Electron and Nuclear Counters," p. 112 (D. Van Nostrand Company, Inc., New York, 1946)
2. D. H. Wilkinson, "Ionization Chambers and Counters," p. 225, 240 (Cambridge University Press, 1950)
3. S. C. Curran and J. D. Craggs, "Counting Tubes," p. 76 (Academic Press, Inc., New York, 1949)
4. S. S. Friedland, *Phys. Rev.* **71,** 377 (1947) **74,** 898 (1948)
5. E. C. Farmer, S. C. Brown, *Phys. Rev.* **74,** 902 (1948)
6. F. W. Brown, P. J. Harris, A. L. Klein, *Phys. Rev.* **75,** 1461 (1949)
7. W. D. B. Spatz, *Phys. Rev.* **64,** 236 (1943)
8. R. K. Soberman and S. A. Korff, *Phys. Rev.* **86,** 584 (1952)
9. H. Paetow, *Z. Physik* **111,** 770 (1939)
10. R. L. Chasson, M. L. MacKnight, *Rev. Sci. Instr.* **24,** 212 (1953)

What are Effects of Radiation on Electronic Components?



Phototubes, bias cells, dry rectifiers may fail to operate in intense fields of neutrons and gammas. But sensitive circuits made of selected components will function normally

RESULTS OF EXPOSURE of electronic components to reactor radiations indicate that most components of conventional circuits will function normally through long irradiation (see table). Exceptions are phototubes, bias cells, germanium and copper oxide rectifiers, resistance-wire strain gages, and some resistors and capacitors. The presence of boron, ionizable gases, or definite crystal structure make components likely to fail. The tests were made by James H. Green,* Victor B. Corey,† and Carl L. Frederick‡ of Frederic Flader, Inc.

Test Procedures

Hole No. 8, the "goat hole," of Argonne's CP-3 heavy-water reactor served for most of the tests. At maximum power, it provided a flux of 10^{11} neutrons/cm²/sec and 10^{10} gamma photons/cm²/sec; irradiations were carried out for a time equivalent to 100 hours in this flux. Some tests were run in the "thimble" of the reactor, where both fluxes are 10 times as great, and one in Hole 6 with fluxes 5 times those of Hole 8.

The reactor interior was at about 90° F during operation. To differentiate between heat and radiation effects, the investigators took readings on control samples. These were kept in an oven that had a controlled temperature equal to that of the reactor.

In most of the tests, components were connected in circuits typical of their usual functions, and data were taken during the irradiation. As a detailed test of circuit operation, a composite photomultiplier assembly was operated during irradiation.

Composite Assembly

A sample circuit was used to represent any electronic sensory and control system that might be used with a reactor. It consisted of exciter lamp, photomultiplier tube, amplifier, matching transformer, and a conventional regulated power supply.

Observation of eleven different variables permitted quick isolation of radiation-induced failures. The argon exciter lamp required increased d-c bias for operation under irradiation. The photomultiplier tube gave a reduced signal; this is believed explained by later tests that show an increased dark current for phototubes under irradiation. Since an a-c signal was taken from the tube, saturation by the dark current probably explains the decrease. An early decrease in the sensitivity of the phototube, with no recovery at shutdown, remains unexplained.

Except for exciter lamp and photocell, no changes were observed in the monitored variables during 145 equivalent hours of irradiation. Signal modulation, output, temperature, and all power-supply voltages were observed in addition to the bias voltage of the argon lamp. Thus, it is believed that sensitive electronic systems will operate satisfactorily under irradiation if the components are properly chosen.

Vacuum Tubes

The table lists the results of tests on grid-controlled electron tubes, diode rectifiers, voltage-regulator (VR) and glow tubes, phototubes, and ballast tubes. All except the phototubes performed without observable effects due to radiation.

Hot-cathode types. Two sets of experiments were conducted in search of any possible effects on grid-controlled electron tubes. Five tubes (6AG7, 6SN7, 6B4G, 6L6, and 6L6G) showed no changes in their dynamic characteristics. More extensive tests with five 6AK6's as test samples and five others for controls showed no radiation effects on either gas pressure or plate resistance. The same type of test was performed on 6SJ7's with negative results. Similarly, 6H6's per-

* PRESENT ADDRESS: Sylvania Electric Products, Inc., Buffalo, N. Y.
† PRESENT ADDRESS: Donner Scientific Co., Berkeley, Cal.
‡ PRESENT ADDRESS: Carl L. Frederick Co., Washington, D. C.

Effects of Reactor Radiation on Electronic Components

Subjects of test	*Number of samples of each type*	*Parameters tested*	*Equivalent irradiation (hr)**	*Results*
Grid-controlled electron tubes				
6AG7, 6SN7, 6B4G, 6L6G, 6L6	1	Dynamic characteristics (μ, g_m, r_p)	103	No significant effect
6AK6, 6SJ7	3	Plate current	433	No effect (±5%)
" "	1	Gas pressure	433	No effect (±20%)
Diode rectifiers				
6H6 (metal)	2	Plate voltage for	150	No effect
6H6 (glass)	2	rated current	150	"
Voltage-regulator and glow tubes				
VR75; argon glow, type AR4; neon glow, type NE21		Ignition, extinction voltages before, during, after irradiation	3‡	No effect (2%)
Phototubes				
Visitron 59-A-5		Output and dark current	3‡	Dark current equivalent to normal output during irradiation. Zero dark current at shutdown. Decreased sensitivity due to radiation-induced blackening of glass
931A, 922, 929, 927, CE-25-C		"	105	
Ballast tubes				
Amperite 1P1 and 920		Voltage-current characteristic	170	No effect
Tube filaments				
Tungsten, platinum filaments	1	Resistance	21	No effect
Capacitors, electrolytic§				
Cornell-Dubilier EB9100X, 10μf, 450 v, aluminum jacket		Leakage current	234	Increased faster in samples than in controls.
		Capacitance	234	Average decreased 14%.
Aerovox GL, 8 μf, 450 v, aluminum jacket		Power factor	234	Increased 3.5–31%.
Cornell-Dubilier BR845, 8 μf, 450 v				
Capacitors, paper and mica				
Bakelite, paper, 0.15 μf, 200 v; tubular paper 0.3 μf, 200 v; mica, 0.01 μf, 400 v	2, 2, 1	Breakdown under 200 volts d-c applied during irradiation	162	No breakdown; capacitance variation 3–20%
Solar MPW (paper), 0.155 μf; El Nenco (mica) 0.0055 μf	1	Capacitance two weeks after completion of irradiation	41†	No effect
Capacitors, tubular paper and oil-impregnated				
Cornell-Dubilier, 0.1 μf, 400 v, paper	12	Capacitance during irradiation	140	Average decrease of 6%
Cornell-Dubilier, 0.1 μf, 400 v, oil	4	"	140	Average decrease of 10% in first 20 hr; additional decrease of 2.5% in next 100 hr
Capacitors, ceramic				
Centralab Hi-Kap 500 μf	4	Capacitance 10 days after completion of irradiation	140	No change due to irradiation (both controls and test capacitors showed decrease in capacitance of about 1%)
Centralab Hi-Kap 1,000 μf	4		140	
Resistors, wire-wound precision				
Ohmite Brown Devil IRC WW4		Resistance	>100	Variation <0.5%

formed without any observable effect.

VR and glow. No effect was observed in either extinction or ignition voltages of irradiated VR75's, argon and neon glow tubes.

Phototubes. Representative types of phototubes were arranged so that light from a constant source would fall on them. Dark currents and outputs varied as shown in the table.

Ballast tubes and filaments. Tests on Amperite ballast tubes and gage tubes especially designed to measure performance of platinum and tungsten filaments showed that neither was affected by the radiation.

Capacitors

The tests indicate that capacitors containing boron should not be used in nuclear radiation fields. This includes all known makes of electrolytics. Other types displayed satisfactory performance generally although some decreased in capacity. One Solar MPW paper-in-bakelite capacitor split open in the radiation field, so this type is not recommended for such applications.

Piercing of the cases of electrolytic capacitors may have prejudiced the results, for evaporation of essential moisture would be harmful to the capacitors. However, the piercing was deemed necessary to make sure that gases liberated would not cause an explosion that would spread boron in the reactor.

Resistors

With the exception of one type, resistors showed only small radiation effects. Wire-wound types are recommended as best among the ones tested.

Unusual difficulties appeared in Continental Carbon's X-1 resistors. In the first tests, the experimenters found rapid decreases of 5–99% in their resistance. Further investigation showed that these decreases occurred whenever the resistor was in intimate contact with paraffin, which was used as a protective coating. Shields of cadmium, friction tape, and aluminum outside the paraffin appeared to increase the effect rather than decrease it.

The effect disappeared when the resistors were irradiated with air or carbon next to them, and resistors shielded by cadmium inside paraffin did not deteriorate.

Noise. Fission-produced radiation has negligible effect on thermal and current-induced noise in resistors. This

conclusion comes from two hours of measurements with both carbon and wire-wound resistors in a flux of 10^{11} n/cm²/sec.

Dry Rectifiers, Crystals

The table shows that different types of dry rectifiers behave very differently in radiation fields. Particularly recommended for use in high fluxes are Sylvania's 1N21 and 1N23 of silicon and Federal's 403-D2625 of selenium.

Peterson and Bliley quartz crystals were used in oscillators that operated in the reactor for 46 days with no changes in frequency. Oscillators using James Knight's H-43 crystals were irradiated in the thimble. Their frequencies after irradiation were the same as before.

Dry Cells

Strong radiation fields cause some deterioration in all dry cells. In general-purpose applications this would cause only a slightly shortened useful life. However, the single type of bias cell tested showed such changes of terminal voltage as to be unusable for intended purposes in strong fields.

The investigators concentrated primarily on size D flashlight cells and hearing-aid cells as representative samples of general-purpose dry cells. In three experiments they divided their cells into four groups: test on open circuit; test under load; control on open circuit; control under load. They made daily readings of terminal voltages with 100- and 10,000-ohm loads.

In the bias-cell experiment, heat caused no appreciable change in the voltage of test cells, but radiation caused unreliability. Voltages were measured by means of a circuit in which the cells were connected to a grid and supplied no current. The conclusion was that bias cells cannot be expected to provide constant grid voltage in intense radiation fields.

Strain Gages

Also unreliable were resistance-wire strain gages. These were strained by energizing relays to which they were bonded for testing. Differences between strained and unstrained output voltages were used as the gage readings. The results showed that radiation has a significant effect.

The experimenters felt some concern lest the bonding materials were causing the effect rather than the gages themselves. However, they observed that the gages showed considerable radiation effect even when they were unstrained. Thus the effect on their readings was probably due to the effects on the gages, irrespective of effects on bonding material and relays.

Effects of Reactor Radiation on Electronic Components (continued)

Subjects of test	*No., of each type*	*Parameters tested*	*Eq. irrad. (hr)**	*Results*
Resistors, carbon				
IRC		Resistance	98	Variation <2%
Allen-Bradley		"	116, 130	"
Resistors, metallized				
IRC, type BTA;		Resistance	100	Variation ~0.5%
Continental Carbon X-1		"	8–162	Erratic changes, +15 to −99%
Dry rectifiers				
Sylvania 1N21, 1N23 (silicon)	4	Resistance and back-to-front ratio	212	No change
Federal 403–D2625 (selenium)	4	"	200	No change
Sylvania 1N34 (germanium)	11	"	—	Rectification totally destroyed after as little as 25 equivalent hours of irradiation
Electrox B4 (copper oxide)	2	"	212	Remained usable, but forward resistance increased
Quartz piezoelectric crystals				
Peterson PR	2	Natural frequency	270	No effect (0.01%)¶
Bliley AX2	2	during irradiation	270	"
Knight H-43	2	Natural frequency before and after irradiation	45†	No effect (0.01%)
Dry cells, size-D-flashlight and hearing-aid				
Eveready size D	2	Voltage, internal	130	(a) Terminal voltage 3–5%
Burgess size D	1	resistance of cells	130	lower for test cells than con-
Ray-O-Vac size D	1	(a) on open circuit	130	trols; internal resistance
Mallory RMB-3	2	(b) with 100-ohm	132	100% greater. (b) Term-
Mallory RMBZ-4	2	load	132	inal voltage 6% lower; in-
Ray-O-Vac hearing-aid	3		113	ternal resistance 250% greater
Dry cells, bias				
Mallory 1-volt	3	Open-circuit voltage	202	Rapid early decrease (~20%) followed by erratic recovery to as much as 12% overvoltage
Resistance-wire strain gages				
Baldwin-Southark Type AD-7	16	Input and output voltages, strained and unstrained	127	Erratic changes in both strained and unstrained outputs (~10%)
Transformers				
Power, output, input types	1, 1, 2	Output voltage with constant input	100	No effect

* Total radiation dose is expressed in terms of equivalent hours at maximum flux. Maximum fluxes are 10^{11} neutrons/cm²/sec and 10^{12} gamma photons/cm²/sec except those marked † or ‡.

† Maximum fluxes were 10^{12} n/cm²/sec and 10^{11} γ/cm²/sec.

‡ Maximum fluxes were 5×10^{11} n/cm²/sec and 5×10^{12} γ/cm²/sec.

§ Cases of electrolytic capacitors were pierced to prevent explosions that might be caused by the gases generated by irradiation.

¶ One Peterson PR crystal ceased to oscillate at times—apparently due to low crystal activity, not irradiation.

Transformers. No radiation effects could be found in the four transformers of various types that were tested.

* * *

Information reported here is from "Effects of Fission Produced Radiation on Electronic Equipment," NEPA-624-FF-13 (1948).

Gamma-Ray Scattering from Thin Scatterers

By DAVID G. CHAPPELL

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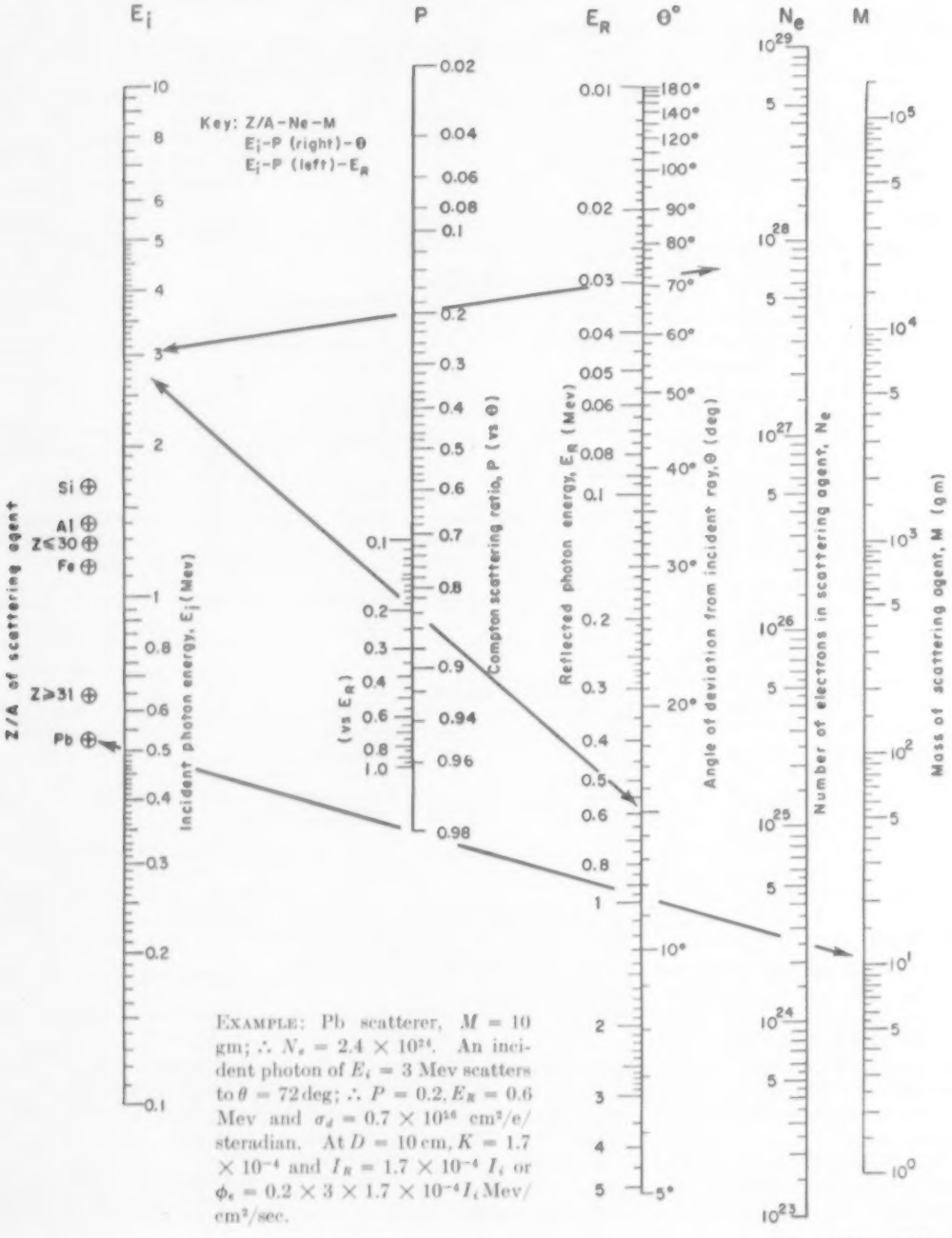

EXAMPLE: Pb scatterer, $M = 10$ gm; $\therefore N_e = 2.4 \times 10^{24}$. An incident photon of $E_i = 3$ Mev scatters to $\theta = 72$ deg; $\therefore P = 0.2, E_R = 0.6$ Mev and $\sigma_d = 0.7 \times 10^{-26}$ cm²/e/steradian. At $D = 10$ cm, $K = 1.7 \times 10^{-4}$ and $I_R = 1.7 \times 10^{-4} I_i$ or $\phi_s = 0.2 \times 3 \times 1.7 \times 10^{-4} I_i$ Mev/cm²/sec.

THESE NOMOGRAMS permit rapid estimation of the photon flux reflected from a thin object; this is often required in shield design.

A photon flux I_i (γ/cm²/sec) of energy E_i (Mev) per photon, incident upon a scatterer thin with respect to the relaxation length of the incident or scattered photon ($t < \lambda$), will scatter through an angle θ to a receiver R at distance D (cm) with an intensity I_R (γ/cm²/sec/steradian) and energy E_R (Mev) per photon and an intensity given by

$$I_R = N_e \sigma_D D^{-2} I_i = K I_i$$

The energy flux, ϕ_s (Mev/cm²/sec/steradian), at R is

$$\phi_s = E_R I_R = P E_i K I_i$$

The scattered photon energy, E_R, is given by the Compton equation

$$P = E_R/E_i = \left[1 + \frac{E_i}{0.51}(1 - \cos\theta)\right]^{-1}$$

The probability per electron of scattering the incident photon through angle θ is given by the Klein-Nishina equation

$$\sigma_D = d\sigma/d\Omega = (P - P^2 \sin^2\theta + P^3) r_e^2/2$$

where the classical electron radius $r_e = 2.82 \times 10^{-13}$ cm and σ_D is in cm²/steradian per electron. One must multiply by the number of electrons in the scattering medium, $N_e = 6.02 \times 10^{23} MZ/A$, to get the total scattering probability.

Large objects must be subdivided into pieces of such size that I_i and θ can be assumed constant over each region of subdivision. Each region is then considered to be a point scatterer defining a new set of parameters M, D, and θ, and the scattered intensities from all subdivisions are summed.

If small values of M are used, K may go off-scale; in this case N_e can be multiplied by a convenient factor of 10 and K divided by the same factor to obtain the corrected value of K.

The value of K is not particularly sensitive to Z/A. However, the average value Z/A for $Z = 2$–30 is plotted at $Z \leq 30$ and for Z/A for $Z = 31$–91 at $Z \geq 31$. This provides for scattering media for which only an approximate composition is known.

* * *

I wish to acknowledge the assistance of Miss Joyce Berger, who drew the nomograms.

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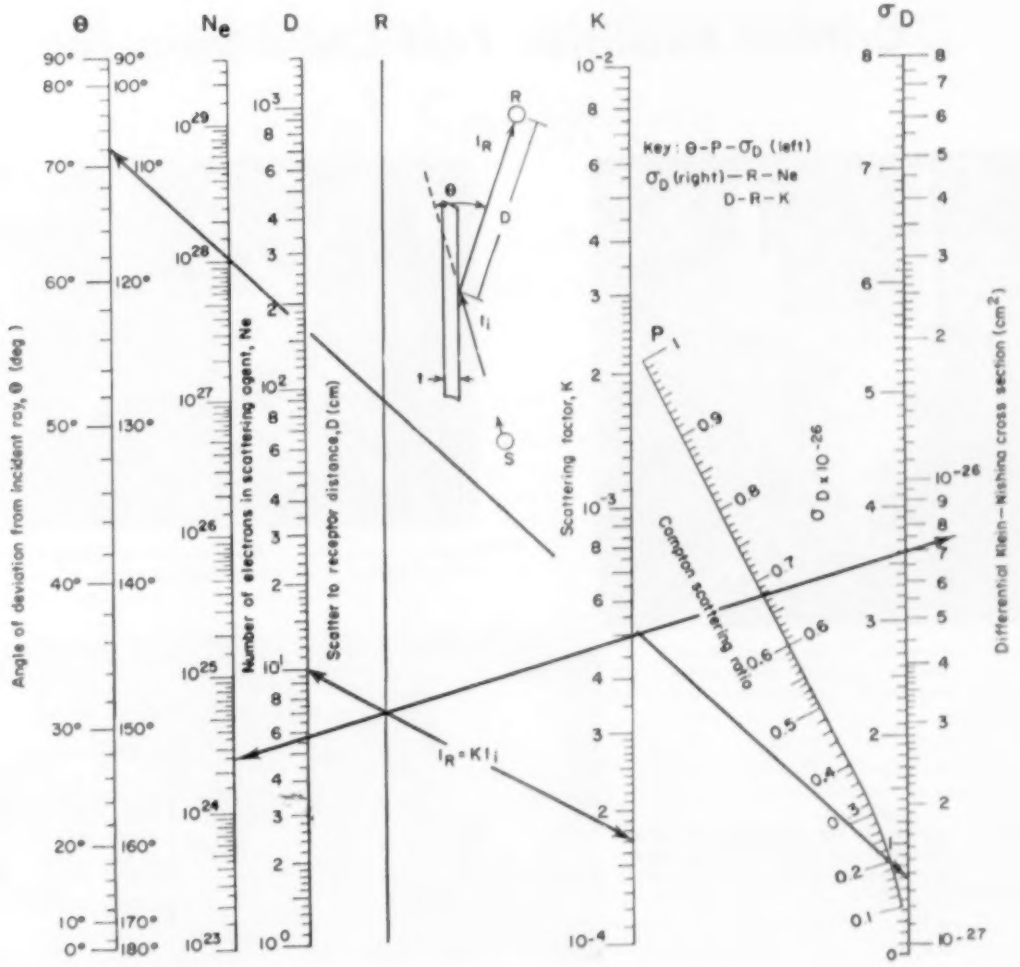
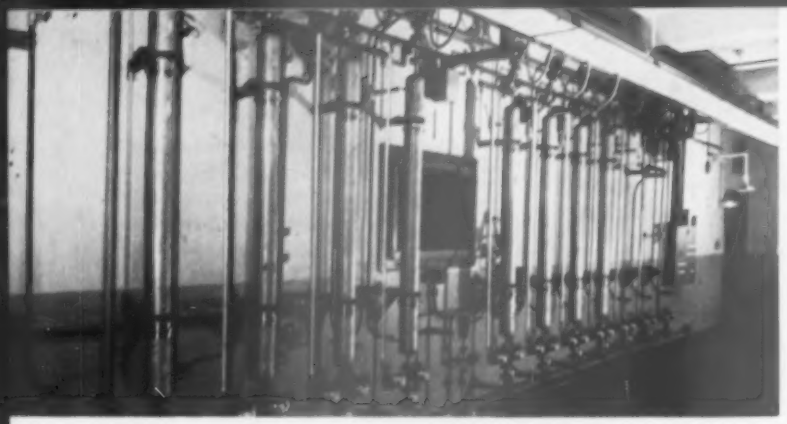
* Knolls Atomic Power Laboratory is operated by the General Electric Co. for the U. S. Atomic Energy Commission.





Storage manifold, above, holds enriched uranium solutions used at Oak Ridge National Laboratory to find conditions that prevent or permit chain reactions. Cylinders are 5 in. in diameter and are mounted on 2-ft centers

At right, an engineer adjusts two interconnected slab-shaped vessels that will be filled with uranium solution to study neutron exchange between process vessels of this type

Critical Facilities Test Conditions for . . .

Aluminum sphere and cross shown above were made for critical experiments with solutions. Cross helped to determine specifications for intersecting pipes

Seven interconnected cylinders can be surrounded with water. Tall cylinders at right contain neutron detectors

Critical Experiments Laboratory has test cell at each end. Shielding walls separate them from control room, offices, shop, etc., in central section

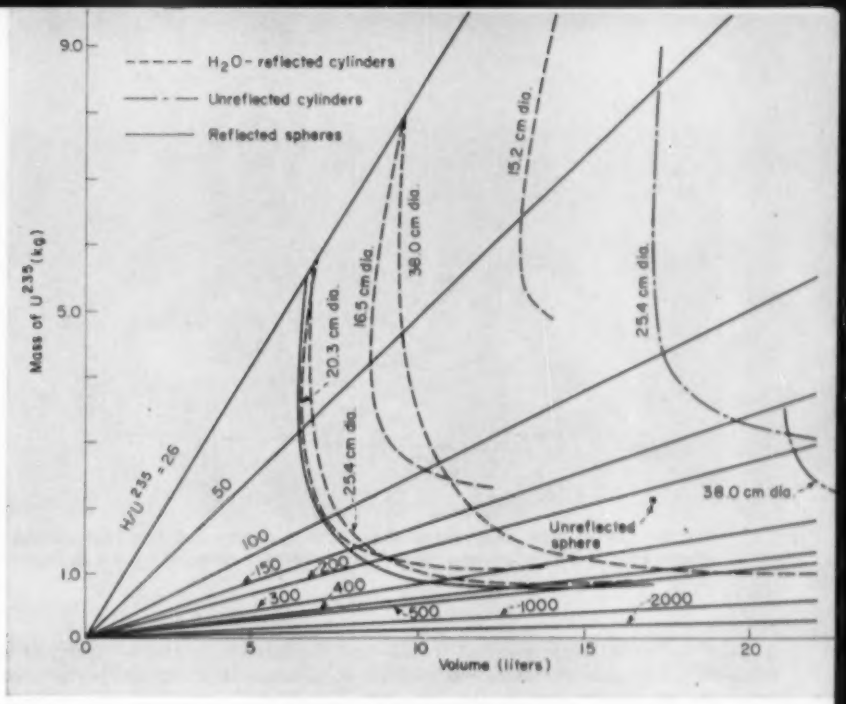


FIG. 1. Critical mass and volume of spheres and circular cylinders containing solutions of $U^{235}O_2F_2$ surrounded by water. Straight lines show mass of U^{235} as function of volume for different concentrations (atomic ratio, H/U^{235}). Dotted curves intersect straight lines at critical masses for cylinders of indicated diameters. Envelope for dotted curves (solid curve, at left) gives criticality parameters for spheres. Also shown are two similar curves for unreflected cylinders (no water) and a point that represents an unreflected critical sphere

Nuclear Safety in Processing Reactor Fuel Solutions

Dimensions, moderation, or concentration can be used to prevent accidental chain reactions. Here are some figures and a suggested method for their use

By DIXON CALLIHAN
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FREEDOM FROM accidental and unscheduled nuclear chain reactions is becoming increasingly important as expansion of nuclear techniques into industry emphasizes economy and safety in services supporting reactor development and operation. Significant parts of any reactor project are preparation of raw fissionable materials, fabrication into fuel elements, and, finally, decontamination and recovery of unburnt fuel residue for refabrication and reuse.

Need for Safety

Raw materials are presently prepared in the AEC-contractor-operated gaseous-diffusion plants and in the production reactors at Hanford. Solid fuel elements are manufactured in certain metal-alloying and cladding processes, and liquid fuels for homogeneous reactors are prepared in appropriate chemical operations.

After use the fuels are sent through chemical separation plants, such as the one at the National Reactor Test Station in Idaho, where residual fissionable isotopes are separated from fission products. In addition to the usual engineering considerations, which are based on chemical and metallurgical requirements and must be applied to all these operations, adequate controls must be used to prevent accumulation of a quantity of fissionable material that will support a nuclear chain reaction.

On the other hand, these controls should not be so stringent as to impair economy of fuel preparation and recovery, for these costs determine, to a large extent, the operating costs of any reactor. Establishment of a balance between adequate safety and minimum cost has been the objective of extensive effort within AEC's activities during the past ten years. This effort has included experimental programs to determine critical (chain reacting) parameters and their application to process operations.

Criticality

In critical experiments, fissionable materials are assembled in prescribed geometries and chemical forms to establish conditions in which they become chain reacting or, in some cases of even more value in these problems, the condition under which they are *not* chain reacting. Experiments may extend from those investigating variations in critical masses of aqueous solutions over a range of concentrations to

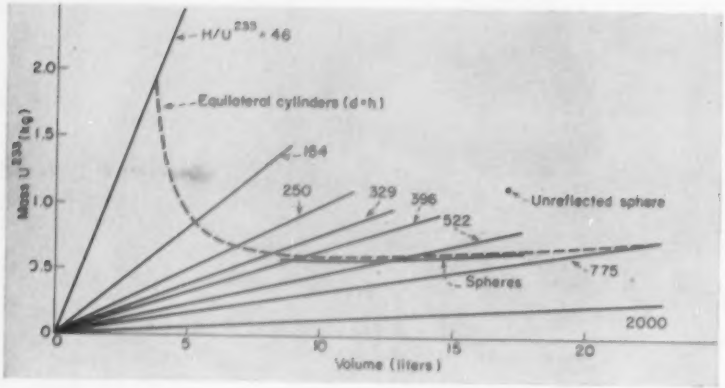


FIG. 2. Critical mass and volume of equilateral circular cylinders (d = h) and spheres for $U^{233}O_2F_2$ in aqueous solution, plotted in the manner of Fig. 1

the test of a single piece of process equipment under operating conditions.

An assembly must contain at least the critical mass of fissionable material if it is to support a nuclear chain reaction. This mass is not single-valued but depends very strongly upon a number of conditions. One that has become of importance in fuel-reprocessing plant design is leakage of neutrons.

Effect of neutron leakage. Leakage depends on vessel shape and the neutron-reflecting properties of surrounding materials. For example, it is possible to specify vessel dimensions, such as pipe diameters, that give a sufficiently unfavorable area-to-volume ratio to prevent a chain reaction regardless of quantity of material contained. If the pipe is encased in a cooling jacket or is near other process equipment or structural materials, this dimension will be less than it would be if no neutron reflector were near.

Effect of moderation. Another condition to which the critical mass of an enriched uranium salt is very sensitive is presence of neutron-moderating nuclei. The critical mass may decrease by a factor of 100 as the water content is increased. But upon extensive dilution the critical mass increases without limit due to the neutron absorption by hydrogen.

Effect of density. Finally, a third determining factor is the density of the fissionable element including as a special case isotopic purity.

The table shows critical values governing homogeneous aqueous solutions of fissionable materials. Different limits must be applied to solid, metallic fuels, not considered here.

Nuclear safety can be incorporated in process-equipment design and in the specification of storage and shipping patterns through one or more of these criteria. For instance, it is possible to construct a fuel-processing plant in which all equipment, including storage vessels, are so sized that no critical accumulation can occur regardless of the quantity of material in process, chemical concentration, or proximity of neutron-reflecting bodies. As another extreme the mass in process at any time can be maintained below the minimum that can support a chain reaction with all other contributing factors optimized.

Practical Approach

The practical approach to nuclear safety is the simultaneous application of two or more criteria so that uneconomic extremes are avoided. In many instances certain process conditions, quite apart from nuclear considerations, provide a significant safety factor. For example, the maximum operable chemical concentration may not be sufficiently low to guarantee a safe process, but it may be low enough to permit relaxation of otherwise stringent size requirements. Thus, the safety of an operation can be assured by the sum of several restric-

Prevent Chain Reaction by Keeping Below One of These

Fissionable material	*Mass (gm)*	*Volume (liters)*	*Cylinder diameter (in.)*	*Slab thickness (in.)*	*Concentration (gm/liter)*
U^{235}†	800	6.3	5.0	1.4	11.6
U^{233}	588	3.5	4.0	~0.5	10.9
Pu^{239}	509	5.0	5.4	1.9	7.8

† ~ 90 % enriched

Critical mass and volume. *These parameters of a critical system are minimal in spherical geometry and the values given for the three isotopes describe critical spherical volumes surrounded by an effectively infinite water reflector. It is emphasized that* **there is no safety factor** *in these quantities and it is recommended that a factor of 2 be applied to the masses to cover batching and analytical errors. Somewhat smaller factors can be applied to the volumes. The chemical concentration at which the critical mass of a particular isotope is a minimum is different from that at which its critical volume is a minimum.*

Critical cylinder diameter. *Solutions of the three isotopes may be safely processed and stored in cylinders having the indicated inside diameters. Safety is imposed by the diameter alone; the container may be of any length, contain any mass at any chemical concentration, and be surrounded by an hydrogeneous reflector.*

Critical slab thickness. *Slab-like volumes of aqueous solutions of infinite extent having these approximate thicknesses will be subcritical when reflected by water.*

Critical concentration. *Aqueous solutions having concentrations below values shown cannot be made critical.*

Any one of these limitations on mass, volume, container dimensions, or fuel concentration will prohibit a chain reaction regardless of other conditions. It is assumed that only materials usually found in chemical processing plants—ordinary water, concrete, stainless steel—are present and that the fissionable element has a density of less than one gram per cubic centimeter in a homogeneous solution sufficiently dilute to thermalize the neutrons.

tions, each impairing the economy only slightly. It is clearly difficult to formulate generally applicable nuclear safety regulations.

An example of experimental data that are becoming available as bases for plant design is shown in Fig. 1, where critical masses of U^{235} in aqueous solutions of UO_2F_2 are plotted as functions of concentration and geometry. The solutions were contained in cylindrical vessels made of aluminum and were surrounded by water, which served as an effectively infinite neutron reflector. The lines from the origin of the graph are lines of equal chemical concentration, expressed as the ratio of hydrogen to U^{235} nuclei, and their intersections with the curves describe the parameters of particular critical systems. A single curve representing critical spherical geometries forms the envelope of the curves for the cylinders. Similar data for U^{233} and Pu^{239} are given in Figs. 2 and 3.

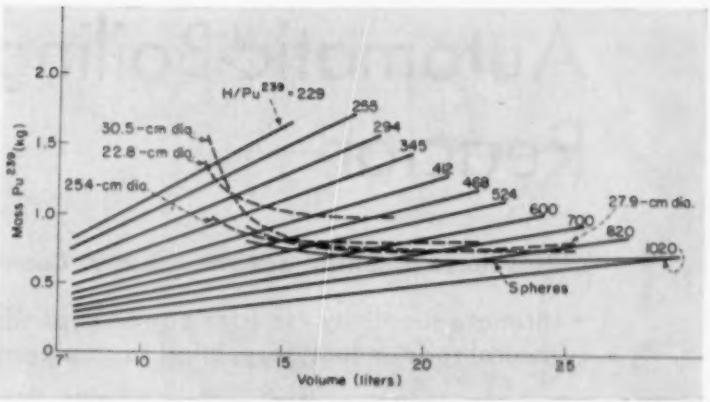


FIG. 3. Critical mass, volume of reflected spheres and cylinders of $Pu^{239}(NO_3)_4$ in aqueous solution, plotted as in Fig. 1

Unreflected Assemblies

If in the process under design it is established that flooding by water is unlikely and other neutron reflectors such as concrete walls, structural members, and personnel are not near, the values of the parameters given above can be increased significantly. This is illustrated in Fig. 1 where the critical conditions of two unreflected cylinders and an unreflected sphere are described. An 8-in.-dia cylinder of aqueous U^{235} or Pu^{239} solution without a neutron reflector will be subcritical with all other characteristics optimized. However the walls of the container must be recognized as a partial reflector.

Dilution of U^{235} with U^{238} does not change the limiting critical mass severely until the composition becomes about 95% U^{238}. At that enrichment the minimum mass is slightly less than 2 kg of U^{235}. The minimum critical volume is about 30 liters and the maximum subcritical reflected cylinder diameter is 10 in. Further decrease in the U^{235} composition increases the limiting values of the parameters markedly since it is believed that a homogeneous aqueous mixture of natural uranium cannot be made critical.

Absorbers

No extensive use has thus far been made of the addition of neutron poisons to process liquids. Unless boron or cadmium is homogeneously distributed in the solution—a method which presents subsequent purification problems—they are not important in terms of either the safety factors they effect or the economic realizations desired in chemical processing. The application of a layer of a neutron absorber to the outside of a vessel increases the critical mass by absorbing neutrons that otherwise enter the vessel from adjacent reflectors or from nearby volumes of fissionable materials. An absorber surrounding a nominally unreflected volume will actually increase nuclear reactivity since it provides additional reflection. Nitrogen in the nitrate solutions often used in chemical processes and Pu^{240}, present as an impurity in Pu^{239}, increase the margin of safety in some instances.

There are no regulations generally applicable to the spacing of a number of individually subcritical components of a system of containers of fissionable materials. The attenuation of neutrons by a 12-in.-thick layer of water provides effective isolation of components that are submerged. Therefore some systems have been designed with the individual vessels sized to be safe even when flooded and with sufficient separation for the water to provide neutron shielding. In the absence of water each vessel must be so far subcritical that the exchange of leakage neutrons among them is insignificant.

Safety Factors

It is desirable to apply some factors of safety where control of a process is effected by mass or concentration limitations rather than by equipment dimensions. A factor of at least two has been used to protect against analytical and sampling errors and against an inadvertent combination of two batches. In most instances the use of this factor has been extended to the design of all aspects of a process by requiring the occurrence of two independent maloperations or equipment failures before a nuclear hazard can arise.

Administration

Administration of nuclear safety is of increasing interest and deserves brief comment. Those processing plants handling significant quantities of fissionable materials in a variety of forms have established groups of qualified physicists and engineers versed in the knowledge of the potential hazards and in methods of their control to serve in an advisory capacity to engineering and production organizations. Problems of installations having less frequent processing operations are often referred to members of these groups.

Programs of experimentation and analysis directed towards more economic design and operation of facilities for processing and transportation of fissionable materials is continuing. The practices of the past have been safe but not necessarily efficient; progress into more liberal procedures must be made with caution.

* * *

Recognition is made of helpful discussions with H. C. Paxton of Los Alamos, W. J. Ozeroff of Hanford, C. L. Schuske of Dow Chemical Company, J. T. Thomas of ORNL, and J. D. McLendon and H. F. Henry of the Y-12 and K-25 plants, respectively, in Oak Ridge.

Automatic-Boiling-Column Reactor—

—Has these potential advantages over "conventional" boiling reactors:

- **Ultimate simplicity (reactor power depends only on feedwater rate, control rods unnecessary, blind startup permissible)**
- **Better load-demand characteristics**
- **Higher reactor powers**
- **High fuel burnups**
- **High xenon-override potential**

By CARL F. LEYSE
Internuclear Company
Clayton, Missouri

DURING THE PAST SEVERAL YEARS considerable attention has been given to natural-circulation boiling reactors primarily because of the simplicity of the direct-boiling power cycle. A reactor based on the once-through steam-generation principle may have significant advantages over natural- or forced-circulation boiling reactors. The ABC (automatic-boiling-column) reactor uses this once-through steam-generation principle in an elongated reactor core that is only partially filled with water.

Basic Concept

The proposed ABC reactor shown in Fig. 1 consists of a cylindrical reactor tank with a water inlet below the reactor core and a steam outlet above the core.

The reflector can be water contained in a separate tank surrounding the core tank as shown or a solid reflector within the reactor vessel itself. There need be no control rods. The fuel can be in the form of plates, rods, or possibly small spheres or cylinders. The major components in the primary loop of such a reactor used for power production would be the reactor, turbine, condenser, and the reactor-vessel feedwater pump.

The reactor, initially empty, is brought to power by pumping water into the reactor tank through the bottom inlet line. The water level rises gradually in the core until the reactor becomes supercritical. The reactor power then rises on a relatively short period, which is primarily a function of the inlet-water pumping rate. The startup flow rate is generally smaller than the full-power flow rate. The startup water flow is provided by a small pump in parallel with the main feedwater pump.

After initial startup transients, the reactor levels off at a power level dependent only on the inlet-water flow rate (provided reactor pressure and inlet-water temperature are not varied greatly). During steady-state operation the lower part of the core is cooled by nucleate boiling while the upper part is cooled by a steam-water mixture. The operating power level of the reactor is raised by increasing the feedwater flow rate and lowered by decreasing the flow rate.

Normal shutdown of the reactor is accomplished by reducing the feedwater rate to that necessary to remove shutdown heat. By maintaining shutdown feedwater flow at a value that keeps the reactor critical at low power, the reactor can be brought to full-power operation quickly with the main feedwater pump merely by increasing the feedwater flow.

Operation without Control Rods

The lack of control rods in the ABC reactor is a major departure from conventional reactors. To establish the feasibility of starting and operating a boiling-water-column reactor without control rods, a short series of experiments was carried out in the SPERT-1 reactor last December. The test results (*1, 2*) show that a reactor in which the fuel assemblies are only partially submerged can be brought safely to criticality and operation at power solely by increasing the core water level by pumping water into the bottom of

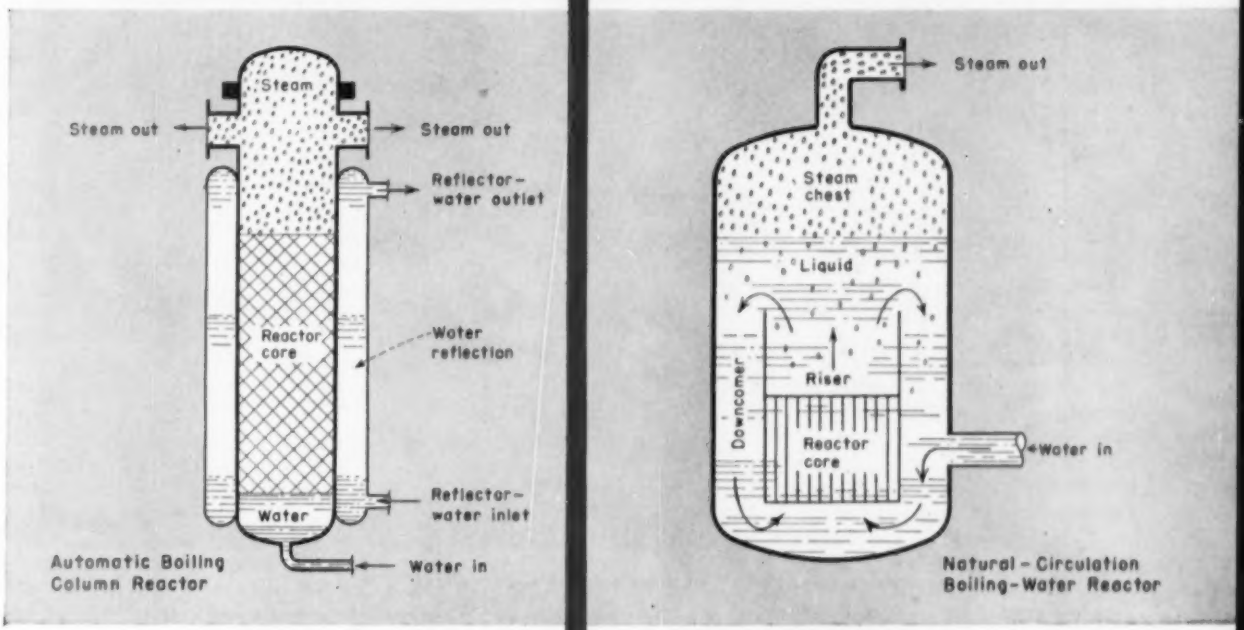


FIG. 1. Startup and operation of ABC reactor are possible without control rods. While "conventional" boiling reactor relies on natural or forced circulation of water, ABC reactor uses once-through steam generation. Since conventional-reactor core is entirely submerged in water, rods are necessary to control reactivity; in ABC reactor, elongated core is only partially in water and inlet-water feedrate (and thus water level in core) control reactivity. Tying turbine governor to inlet-water regulator would provide automatic electric-load-change response

the reactor at a constant rate. Figure 2 shows results of a typical test in the SPERT series.

It is important to note that in the SPERT-1 reactor the core water and reflector water are not separated as in Fig. 1. Thus the inlet water is not forced through the core but instead raises the general water level in the core and reflector. Thus the power would not be expected to level off very soon at a value consistent with the inlet-water flow rate. This is apparent in the test of Fig. 2 where a major portion of the heat went to heating up the large bulk of subcooled water in the reactor tank and the power level (450 kw) at the end of the test is still far above the 310 kw that would correspond to a flow rate of 2 gpm (60° F inlet).

An important objective of the tests was to show that the portions of fuel plates out of the water would not experience any excessive temperatures either during startup or operation. Before each test the water level was lowered below the critical water level and the control rods were raised completely out of the reactor core. The water flow into the reactor was then started and maintained at a constant rate throughout the test. Figure 2 shows the results of a test with an inlet-water flow rate of 2 gpm, which corresponded to a reactivity addition rate of about 0.25% $\Delta k/k$ per minute. The addition of water gradually increased the reactivity of the reactor, causing it to go supercritical at a low neutron level. The reactor power then increased on a relatively short period (3.1 sec) until the formation of steam in the core reduced reactivity and reversed the power rise. Comparison of temperature curves of fuel-plate thermocouples No. 7 (near core center) and No. 1 (above water level) during the initial transient shows that the power transient is terminated by steam formation in the central portion of the core while the fuel above the water line experiences only a gradual temperature increase. During the last several minutes of the test TC 7 is in the nucleate boiling region and TC 1 is in the steam-water region—both temperatures are approximately at the saturation temperature.

Figure 3, a vertical neutron-flux distribution for the test, shows how the large amount of void in the top of the core results in a relatively low power in the top of the fuel. This, of course, is the reason high temperatures do not occur in the steam-cooled portion of the fuel.

The complete test series (*1*) included tests with reactor-tank bulk-water temperatures from 60° F to 200° F and inlet-water flow rates from 2 to 8.5 gpm. The minimum startup period was about 0.5 sec, and the maximum power during the startup transient was about 860 kw. In none of the tests did the temperatures of fuel plates above the water level exceed the saturation temperature by more than about 5° F.

Blind Startup

Startup without nuclear instrumentation in the subpower range is generally referred to as "blind" startup. Blind startup of a reactor is desirable since it eliminates the need for considerable control and nuclear instrumentation in the subpower regions and

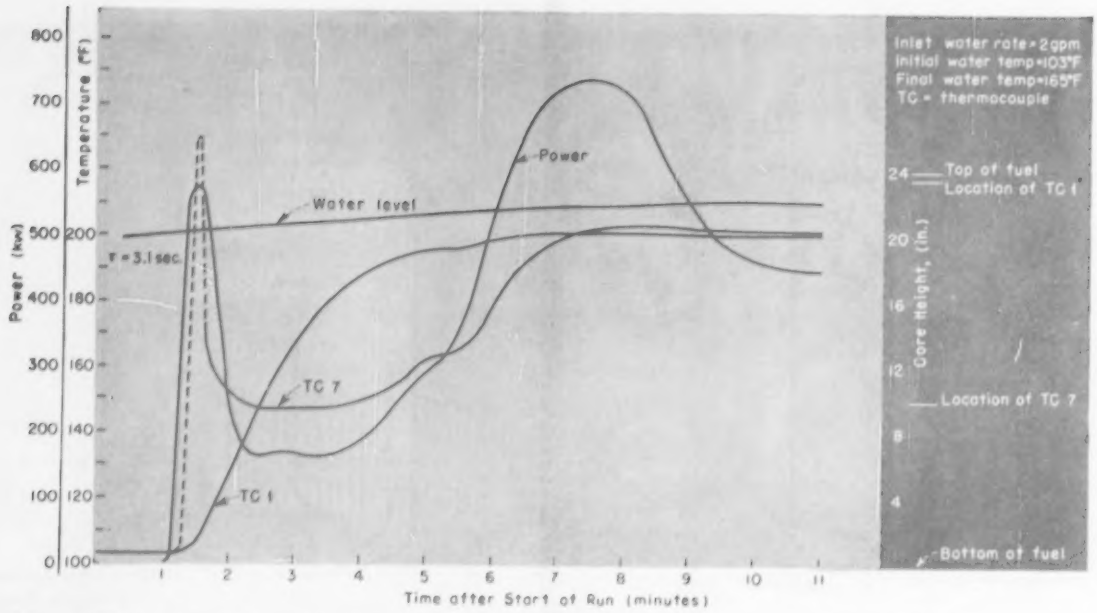


FIG. 2. SPERT-1 test results showed feasibility of boiling-water-column startup and operation without control rods

simplifies reactor operations and maintenance.

The SPERT-1 tests show that a heterogeneous water-cooled and moderated reactor can be brought safely to operation at power solely by increasing the water level in the reactor core.

The experimental evidence indicates that use of this startup procedure in the ABC reactor precludes the necessity for subpower startup instrumentation since the startup pumping rate can be made such that the reactor would not experience excessive power, temperatures, or pressures during the startup transient. Also with startup periods of about 1–5 sec, or even less, being feasible the value of extensive subpower startup instrumentation is questionable.

Load-Change Response

In a conventional steam power plant electrical load changes are sensed by the turbine governor and transmitted (a) to a steam valve that regulates steam flow to the turbine; (b) to an automatic combustion control system that controls the supply of fuel and air to the boiler; and (c) to an automatic feedwater regulator that controls the supply of water to the boiler. The governing response through (a) is rapid but not so rapid for (b) and (c).

In the natural-circulation boiling-water reactor the decrease in reactor pressure resulting from increased steam flow for increased load causes some core water to flash to steam and the associated moderator loss results in a reactor power reduction. Corrective action in the form of control rod withdrawal is necessary to compensate for the reactivity lost because of the additional steam requirements.

In the ABC reactor it appears that automatic response to electrical load changes can be achieved without control rods. In this type reactor the reactor power and steam flow depend only on the feedwater rate. At steady-state conditions the reactor power automatically adjusts itself to that power necessary to convert all the incoming feedwater to steam, since any tendency to operate at a lower power would result in an increase in the effective water level, increase in reactivity, and increase in power. The reverse effects would result from a tendency to operate at a higher power. Proper load-demand characteristics for electrical load changes could be obtained by tying the feed-water regulator to the turbine governor.

In the ABC scheme, decrease in turbine speed due to increased load would be reflected in increased feedwater flow to the reactor, increased reactor power, increased steam flow to the turbine. Decreased load has the reverse effect.

Reactor Power

In a natural-circulation boiling-water reactor, fluctuations in density as the moderator boils cause unstable power when the steam volume fraction is still relatively low, probably 20–30%. Since the water entering the bottom of the core is only slightly subcooled, practically all the power goes to net steam generation and only low-power (say 10–20 kw/liter) outputs appear feasible.

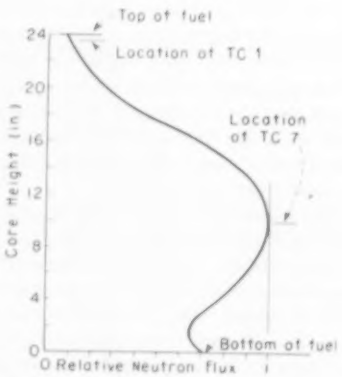


FIG. 3. Vertical neutron-flux distribution for Fig. 2 test

In the ABC reactor, the feedwater is sent directly from the turbine condenser to the reactor and is therefore appreciably subcooled. In a reactor operating at 600 psi the amount of subcooling would be approximately 400° F. It is probable that an ABC reactor could be designed so that the steam emerging from the top of the core would be of high quality or even slightly superheated. Whether or not such operation can be satisfactorily achieved must be determined by experimental studies with a prototype test reactor, since the distribution of steam, the power distribution, and the reactivity are interdependent.

The success of the ABC-type reactor will depend much upon the ability of the steam to leave the core without carrying along appreciable water. The high steam velocities relative to water measured by Argonne (*3*) indicate that low water content in the steam leaving the core is probably attainable. If such is the case then the ABC reactor may not exhibit the instability caused by moderator fluctuation in natural-circulation boiling-water reactors since large density fluctuations would not be likely in either the subcooled water in the lower portion of the core, or in steam in the upper portion. Also, it is not improbable that the water reflector above the core in a natural-circulation boiling reactor and the natural circulation itself contribute highly to the instability.

If the ABC reactor is found to be inherently stable then it should be capable of much higher powers than natural-circulation boiling reactors since the reactivity will be maintained by the subcooled water in the lower portion of the core, and narrow water channels can be used without large reactivity losses because of steam formation in the lower part of the core. Also, since heat removal in the subcooled region will be largely by nucleate boiling, surface heat fluxes equal to or greater than those realized in pressurized-water reactors may be attainable.

High Fuel Burnup

In the ABC reactor, lengthening the reactor core life for a given core diameter and composition is accomplished by increasing the vertical length of the core.

During the early stages of operation heat is generated in the bottom portion of the core as shown by Fig. 4.

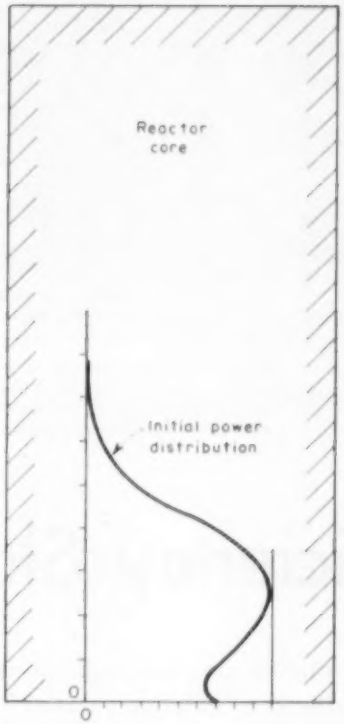


FIG. 4. Initial vertical power distribution for typical ABC-reactor core

As energy is extracted from the core the point of maximum power gradually moves upward, but the lower portion of the core continues to contribute appreciably to reactor power until its fuel has been largely depleted.

When the core has run its useful life, the lower portion of the core would be removed for reprocessing while the upper slightly depleted portion would be moved to the bottom part of the core and new fuel placed above it. In this way it is possible to attain very high burnups in the fuel assemblies removed for reprocessing. In fully enriched reactors burnups in excess of 75% would be entirely feasible.

It may appear that a long core leads to high fuel inventory in the reactor. This need not be quite as bad as it first appears since it is not necessary to initially place the full length of the core in the reactor. The reactor could first be loaded only partially and subsequent additions made to the top of the core as burnup proceeds in the lower parts.

Xenon Override

In reactors operating at neutron fluxes of 10^{14} neutrons/cm²/sec and higher, the buildup of xenon after shutdown results in large reactivity losses. If such a reactor is to be capable of being started up at any time after shutdown, this loss must be compensated for by excess reactivity built into the reactor and counteracted by control rods.

In the ABC reactor, xenon override is readily achieved during the greater portion of the reactor core life since the xenon is concentrated in the lower portion of the core and the water entering the core automatically seeks a higher effective level, which would essentially give a new clean core above the poisoned portion. As the xenon is burned out during operation the effective water level would gradually recede. This xenon override characteristic may have important applications in the propulsion field.

Conclusions

Because of its simplicity in design and operation and the high burnup in fuel removed for reprocessing, the ABC-type reactor may be economical even for power reactors of relatively small size. In this capacity it would be suitable for multiple-unit use in large power-generating stations. Quite independent of its economical worth, its simplicity alone makes it ideal for power-package use at remote locations.

Although of a limited nature, the experiments (*1*) on startup and operation conducted thus far clearly show that the ABC-type reactor is worthy of more extensive study. The final answers on its over-all practicality will have to come from experiments with a prototype test reactor.

* * *

Much of the material presented was originated by the author while in the employ of the Atomic Energy Division, Phillips Petroleum Co.

The preliminary tests reported were carried out by Phillips Petroleum Co. as operator of the SPERT facility under AEC contract. The author wishes to thank the entire SPERT group, particularly W. E. Nyer, S. G. Forbes, G. O. Bright, T. R. Wilson, F. L. Bentzen, and F. Schroeder, for their consultation and assistance in conducting the tests.

BIBLIOGRAPHY

1. C. F. Leyse. Preliminary feasibility tests for the boiling column reactor, Phillips Petroleum Report PTR-39 (1956)
2. W. E. Nyer. Transient Experiments with the SPERT-1 reactor, NUCLEONICS **14,** No. 6, 44 (1956)
3. S. A. Untermyer. Boiling reactors: direct steam generation for power, NUCLEONICS **12,** No. 7, 43 (1954)
4. C. F. Leyse, "Reactors," Phillips Petroleum Co., letter Ley-7-55 A, March 8, 1955

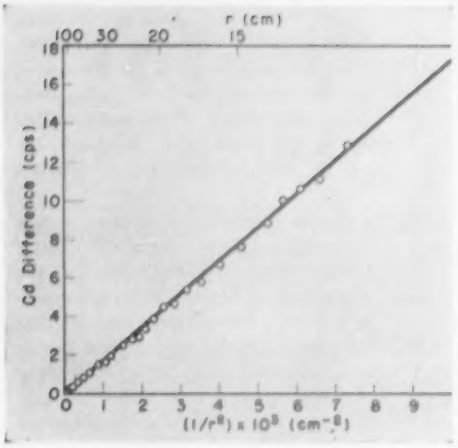


FIG. 1. Counting rate for a spherical neutron source vs inverse square of the distance. Although not well shown by the figure, effect of room scattering becomes appreciable at large *r*

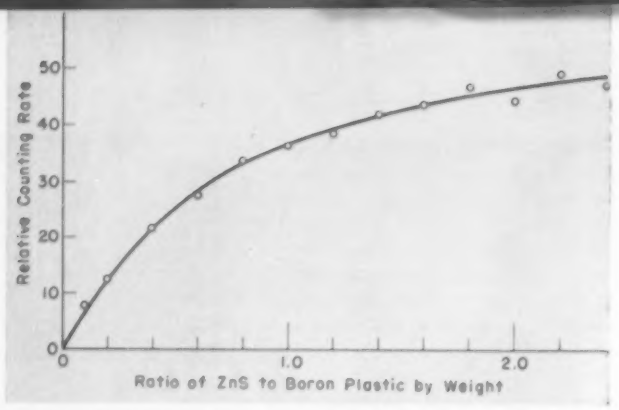


FIG. 2. Relative efficiency of neutron phosphor as a function of composition. Phosphor thickness = 1.25 mm

High-Efficiency Slow-Neutron

A mixture of boron-containing plastic and ZnS(Ag) phosphor has been optimized to give slow-neutron counters with 33% efficiency yet only 1% gamma-ray contribution when counting radiations from a Po-Be source. Construction and optimization are given

A SLOW-NEUTRON SCINTILLATOR such as the ZnS(Ag)–boron-compound type (*1–6*) described here operates in three principal, closely related stages:

1. A slow neutron passing through the scintillator is captured by a B^{10} nucleus.

2. The resultant energetic alpha particle reaches a ZnS(Ag) granule with sufficient residual energy to cause a scintillation.

3. Light from the scintillation travels to the photomultiplier photocathode and reaches it with sufficient intensity to cause a recognizable pulse at the anode.

The net efficiency of the scintillator is related to the probability that all three of these events proceed in succession, that is, to the product of the separate probabilities for each of the three events.

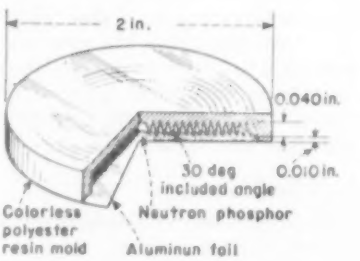
The probability for event **1** is $P_c = 1 - e^{-N\sigma}$, where σ is the microscopic slow-neutron capture cross section of B^{10}, and N is the areal density of B^{10} nuclei. This equation holds so long as there is little competition with slow-neutron capture in the scintillator; this has been the case with all the scintillators examined in this study. The larger N is, the greater is P_c, but that as P_c approaches unity, further increases in N accomplish very little.

The probabilities for **2** and **3** are not susceptible to such direct analysis. The probability of **2**, of the resultant alpha particle reaching the ZnS(Ag), depends on the density of material, the path length involved, and the minimum residual energy required. These, in turn, depend on secondary factors such as relative amount of ZnS(Ag) in the material, size and shape distribution of the ZnS(Ag) particles, and the minimum usable light per scintillation.

The probability of **3**, of sufficient scintillation light reaching the photomultiplier, depends on the strength of the scintillation, the transmissivity of the light path to the phototube, the

Grooved Scintillators Are Best

A thin scintillator made with a grooved or corrugated surface provides more scintillating material, and hence more B^{10} per unit projected area of scintillator, while maintaining a usable light transmittance. Such a scintillator was made by using a transparent Bioplastic mold, cast from a negative steel mold (see figure). The scintillator was cast at about 180° C and moderate pressure in the plastic mold. It was used with the grooved scintillator surface facing the photomultiplier, and with an aluminum foil covering the opposite surface. The improvement in scintillator efficiency was ~60%, resulting in an over-all efficiency of about 33% for thermal neutrons at a discriminator setting such that Po-Be gamma rays gave only 1% as many counts as thermal neutrons.



Improved slow-neutron scintillator

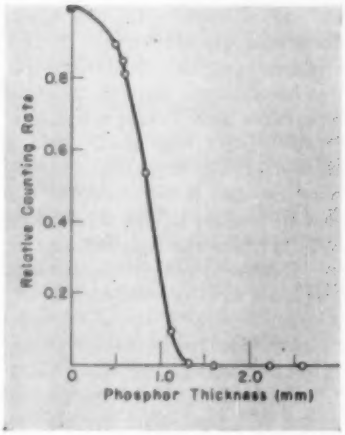


FIG. 3. Transparency of neutron phosphor to the Po-α scintillation of ZnS

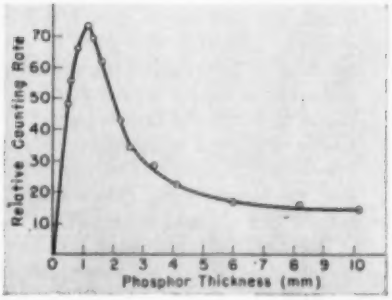


FIG. 4. Relative efficiency of neutron phosphor vs. phosphor thickness. ZnS:BP = 2.0

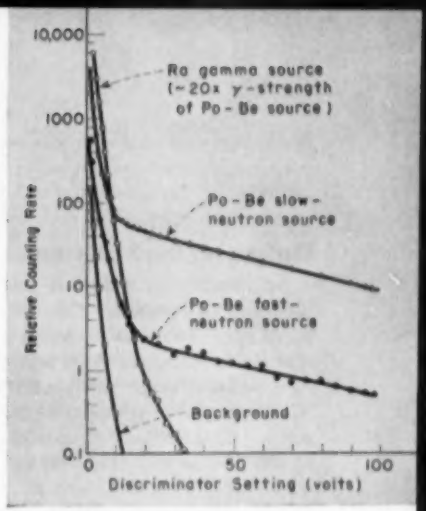


FIG. 5. Response to neutrons and gamma rays vs discrimination level

Scintillation Counters

By K. H. SUN, P. R. MALMBERG, and F. A. PECJAK
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East Pittsburgh, Pennsylvania

sensitivity of the photomultiplier, and the amount of background noise present. This probability is further complicated by secondary factors such as length of light path, transparencies of the media comprising the path, number of interfaces between different media in the light path, and transmissivities of such interfaces.

Consideration of these various factors shows that a change in certain of them may be favorable to one of the three main stages involved in counting a slow neutron, and unfavorable to one or both of the other two. Thus, increasing the proportion of ZnS(Ag) in the scintillator increases the probability of an energetic α-particle reaching the ZnS(Ag), but reduces the probability for neutron capture and renders the scintillator more opaque. Because of the complexity of these many factors and their interrelationships, development and optimization of the slow-neutron scintillator has been on an empirical basis.

What was optimized? We aimed primarily at high efficiency, ease of manufacture, and low cost. Although the primary consideration of merit for a scintillator is usually the counting efficiency for a specific type of radiation, other factors can be important, depending on the intended use. Examples are: sensitivity to other types of radiation, inherent noise level, usable counting life, and ruggedness.

Test Equipment

To test the scintillators we needed only slow-neutron sources and some standard electronics.

Slow-neutron sources. A slow-neutron source with minimal spurious radiation was required to obtain the relative efficiencies of the neutron scintillators as a function of a given design parameter, and to measure absolute efficiencies of the better scintillators. Two sources were used, each consisted of a Po-Be fast-neutron source surrounded by paraffin moderator. The Po-Be sources were 0.7-in.-diameter 0.7-in.-long cylinders and emitted $\sim 2 \times 10^6$ fast neutrons/sec.

In one of the slow-neutron sources, the Po-Be source was fixed at the center of a 6-in. cube of paraffin in a thin steel case. This source was used for obtaining most of the comparative data.

The second source consisted of an 8-in.-diameter sphere of paraffin in a $\frac{1}{16}$-in.-thick aluminum shell, the Po-Be source being fixed at the center. J. A. DeJuren of the National Bureau of Standards calibrated the thermal-neutron flux at the surface of this sphere against the Bureau's absolute-neutron-flux standard, using manganese-foil-activation and cadmium-difference techniques (7). The flux was determined with an accuracy of $\pm 10\%$, and was about 24 thermal neutrons/cm^2/sec at the outer surface.

This spherical neutron source provides a simple $1/r^2$ relationship of neutron flux to distance from source. Thus the absolute counting efficiency can be determined for a given scintillator at an arbitrary distance r from the source center. Careful measurements of relative thermal neutron flux versus distance from the source center were made with the cadmium-difference method, using one of the better scintillators shielded from stray or externally reflected radiation by suitably disposed sheet cadmium. Figure 1 demonstrates that the $1/r^2$ relationship does hold quite well for this source.

Circuitry. Both the 2-in. DuMont 6292 and 5-in. DuMont K1198 photo-

multipliers were used with conventional positive-grounded dynode voltages and cathode-follower output feeding a linear amplifier, discriminator, and scaler.

Optimizing the Scintillator

An iterative procedure is generally required to optimize this type of scintillator. Parameter limits for a reasonable scintillator were established by a series of rough preliminary tests. These were followed by a more exacting series. The criteria examined most closely were sample thickness and ratio of ZnS(Ag) to boron plastic.* Other factors investigated included particle size, type, or brand of ZnS(Ag) and its particle size, light attenuation characteristic of a fixed-composition scintillator, ratio of boric acid to glycerol in the boron plastic, and response of the scintillator to fast neutrons and gammas.

ZnS(Ag):boron plastic ratio. Initial work showed that a high ZnS(Ag): boron plastic (BP) ratio would be advantageous and that the optimum thickness would be ~1–2 mm. On this basis, a series of scintillators 5 cm in diameter × 1.2 mm thick of varying ZnS(Ag): BP ratio were compared in a slow-neutron flux. These tests, the results of which are shown in Fig. 2, established that the neutron counting efficiency increases with ZnS(Ag):BP ratios up to 2.2:1; maximum efficiency seemed to be not far beyond that ratio. Experimentally, this ratio is limited by mixing difficulties at the higher values, where the mixtures become quite dry. For this reason, the quite-workable ratio of 2:1 was used subsequently.

Thickness. The variation with scintillator thickness of its transmittance for light from an alpha-particle scintillation was studied briefly. A Po^{210} alpha-source was covered with a ~10-μ layer of ZnS(Ag) and the combination used as a scintillation light source. Scintillators of 2:1 ZnS(Ag):BP 2.4 cm in diameter and of various thicknesses were interposed between this light source and the photomultiplier tube. Figure 3 shows that scintillators of this composition become rather opaque to the scintillation light when thicker than 1 mm or so. These measurements are at a discriminator setting such that maximum sensitivity without excessive background is obtained.

More detailed experiments on thickness versus scintillator efficiency were conducted using a series of scintillators ranging from 0.5 to 10 mm in thickness. The results are shown in Fig. 4. It will be noted that a pronounced maximum occurs when ~1.2 mm thick.

Boric acid:glycerol ratio. To find the best ratio of boric acid to glycerol in the boron plastic 5-cm-diameter × 1.2-mm-thick disks having a ZnS(Ag): BP ratio of 2:1 were used. Past a boric acid:glycerol weight ratio of 4:1, further increases in boric acid did not materially increase the fractional boron content nor, consequently, the counting rate. However, the higher ratios make the material less hygroscopic. Hence, the earlier decision to use a 6:1 ratio for most studies emerged as a good one.

Types and sizes of ZnS(Ag). Using 2:1 ratio of ZnS(Ag):BP and 5-cm-diameter × 1.2-mm-thick disks as before, relative counting efficiencies were determined for five commercial ZnS (Ag) phosphors—Du Pont 2B1 (formerly 1410), Sylvania CR20 and 132, and RCA 33Z20A and F2030. The results indicate that the Du Pont 2B1 phosphor is somewhat superior for this particular application. The average grain size of this phosphor is about 10 μ.

To get some idea of the effect of particle size on efficiency, fractionated Du Pont 2B1 of grain sizes 6 and 10 μ, and 25-μ Du Pont 1101 were compared with the regular unfractionated 2B1 phosphor. These tests showed that the unfractionated phosphor was as

* Preparation is discussed below.

Preparation of Slow-Neutron Scintillators

To make a good slow-neutron detector of the type described, the boron-containing material should be transparent and colorless, contain a large proportion of B^{10}, and be susceptible to intimate mixing with the ZnS(Ag). There are two methods that suggest themselves for the combining of ZnS(Ag) powder with the boron-containing material. One, using the boron substance also in the powdered form, is simply to mix the two powders together and then press the mixture into a compact disk. The second is to employ a boron material which can be prepared initially in liquid form, mixing the ZnS(Ag) with it while liquid, and subsequently solidifying the combination. The second method, while usually more difficult, provides more intimate contact between the ZnS(Ag) and the boron compound and is the method used for most of the scintillators considered here.

A number of boron compounds fulfilling the requirements for transparency and freedom from coloration can be found, such as BN, B_2O_3, or H_3BO_3. The BN contains more boron (43.5 wt %) but is refractory and does not melt at temperatures below the sublimation temperature for ZnS. Therefore, it is unusable in a liquid form. B_2O_3, containing 31.1 wt % boron, melts at about 580° C. It is very viscous even at 1,000° C and hence difficult to manipulate. Although it is possible to lower the viscosity of molten B_2O_3 by addition of small amounts of oxides or fluorides of alkali metals, there remains the high melting temperature which tends to harm the luminescent properties of ZnS(Ag).

Preparation of Boron Plastic (BP) and HBO_2

Two boron compounds that have proved especially suitable for this application are

1. *A borate polyester plastic containing as high as 20% boron, hereafter referred to as boron plastic or BP,* 2. *HBO_2 glass, containing about 26% boron. Both are quite readily incorporated with the ZnS(Ag) without harming it.*

BP. *The combination of boric acid and glycerol ($C_3H_8O_3$) to form a colorless, transparent polyester plastic has been known for some time. The molar proportions commonly used are 1:1. To increase the relative proportion of boron in this plastic, various weight ratios of boric acid to glycerol, ranging up to 10:1, were examined. At this high ratio, the viscosity of the polyester melt becomes high, and there is danger of charring. The boric acid:glycerol weight ratio of 6:1 (about 9:1 molar ratio) proved to be the highest that would permit ease of handling of the plastic, and is the ratio which was used for most of the work.*

Boron plastic of 6:1 weight ratio was prepared according to the following receipt: 20 gm of glycerol is first heated to near boiling in a round-bottom 200-ml flask. Then 120 gm of crystalline H_3BO_3 is gradually added with continuous shaking and heating. The initial reaction is rapid, the H_3BO_3 disappearing quickly with considerable liberation of steam. As the reaction proceeds, solution of H_3BO_3 takes place more gradually. At the moment the final H_3BO_3 has been added and dissolved, the clear liquid boron plastic is poured onto a cold thick aluminum plate. The slightly cloudy and brittle plastic which results upon cooling is then stored in a dessicator in polyethylene bags until subsequent remelting and combining with ZnS(Ag). This intermediate cooling state facilitates the many weighings necessary in combining the BP and ZnS(Ag) in varying proportions for efficiency comparisons, but could be dispensed with in preparing a large number of scintillators of fixed composition. If the heating of the molten BP is prolonged at the last stage, the cooled material will be clear and glasslike, and further heating will initiate charring. The heat delivered in the remelting stage will usually remove sufficient additional water to render the BP, as incorporated in the neutron scintillator, clear and colorless. Prepared

good as other sizes. Therefore unseparated Du Pont 2B1 phosphor was used in all other tests.

Scintillator Response

The response of the scintillator to gamma rays, slow neutrons and fast neutrons is shown in Fig. 5. It is clear that gamma rays of the intensity present in the Po-Be neutron source (0.1 mr/hr when neutron flux was 24 n/cm²/sec) can be easily discriminated against. Although the hydrogen content of the scintillator makes it slightly sensitive to fast neutrons, the counting efficiency for them is very small. In critical measurements of thermal-neutron fluxes, correction for fast-neutron counts can be made by Cd difference.

Absolute efficiency. A 2.40-cm-diameter scintillator was used in measuring the absolute efficiency of boron-plastic slow-neutron scintillators of optimized thickness (1.2 mm) and ZnS(Ag):BP ratio (2:1). The experiment was performed with the scintillation counter set in front of the calibrated slow-neutron source. Using the thermal neutron flux calibrated at the surface of the spherical source, together with the $1/r^2$ flux dependence and the measured area of the scintillator, it was possible to evaluate the absolute efficiency straightforwardly.

With discriminator set so that the response to gamma rays from the Po-Be source (0.1 mr/hr when neutron flux was 24 n/cm²/sec.) was slightly less than 1% of thermal-neutron response the efficiency of the scintillator for thermal neutrons was 21%. Note that if gamma-rays are of much greater relative intensity than from the Po-Be source, the interference at this discrimination setting can be appreciable.

Conclusions

The scintillation counter has advantages of ruggedness, better time resolution, and superior geometrical definition when compared with BF_3 counters. The boron-containing neutron scintillator developed in the present investigation is believed to be more efficient for thermal-neutron scintillation counting than other similar scintillators. A measured efficiency of 33% for thermal neutrons has been obtained with the boron-plastic-type scintillator having one corrugated surface; from this an efficiency of 37%, can be estimated for a similar scintillator of the HBO_2 type. This scintillator can be further and markedly improved by using pure or enriched B^{10} instead of natural boron, which contains only 19 wt% B^{10}.

Because of the high neutron counting efficiency of this scintillator and the large-area, thin-sheet geometry of the sensitive volume, it is possible to obtain a large solid angle for interception of neutrons from uncollimated sources.

The neutron scintillator developed here is also being used in photographic detection of neutron patterns.* The photographic sensitivity has been found to be considerably greater than any previously known. These results will be reported later. (See p. 81—Ed.)

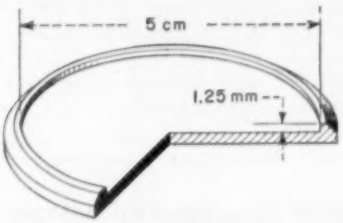
* * *

We are grateful to Michael Giuliano for his assistance in investigating the use of HBO_2 in slow-neutron scintillators.

BIBLIOGRAPHY

1. K. H. Sun, Method of detecting elementary particle, U. S. Patent 2,534,932 (Applied June 19,1947—Granted December 19, 1950)
2. F. Sachs, Neutron detectors, Y-B4-18 (1951)
3. D. E. Alburger, A slow-neutron detector, BNL-1233 (1952)
4. E. Gatti, E. Germagnoli, A. Persano, E. Zimmer, Boron-layer scintillation neutron detectors, *Nuovo Cimento* **9,** No. 9, 1012 (1952)
5. P. G. Koontz, G. R. Keepin, J. E. Ashley, ZnS(Ag) phosphor mixtures for neutron detection, *Rev. Sci. Instr.* **32,** 154 (1955)
6. C. O. Muehlhause, Neutron scintillation counters, NUCLEONICS **14,** No. 4, 38 (1956)
7. J. A. De Juren, H. Rosenwasser, Absolute calibration of the NBS standard thermal-neutron density, *J. Research Natl. Bur. Standards* **52,** No. 2, 93 (1954)

* In cooperation with E. O. Wollan of the Oak Ridge National Laboratory.



Metal mold for neutron phosphor

this way, the BP contains about 19.5 wt % boron and has a density of 1.5 gm/cm³.

HBO_2. *Not too well known is the fact that H_3BO_3 can be converted at moderate temperatures to a clear liquid of the approximate composition HBO_2. About 5 hr at 210° C is required to effect this for 200 gm of H_3BO_3 in a covered 600-ml beaker. The HBO_2 glass prepared in this manner can be poured onto a cold aluminum plate to harden for dessicator storage. The measured boron content of this material is 25.5–26.5 wt % as compared with 24.7% computed for the formula HBO_2.*

Assembly of Slow-Neutron Scintillator

The final step in fashioning a neutron scintillator from the boron compounds just described consists of remelting, stirring in appropriate amounts of ZnS(Ag) powder, pouring or pressing into suitably shaped molds, and cooling. Much experimentation transpired before the present procedures were evolved.

Using boron plastic (BP). *A specific amount of BP was weighed out and remelted in an oil bath at 160° C, the temperature at which the neutron-scintillator mixture becomes workable. A proportionate weight of ZnS(Ag), also preheated to 160° C, was added to the melt with constant stirring and mixing. To prevent charring the boron plastic from prolonged heating, mixing was completed in one minute or less. The mixture was then transferred to a metal mold such as that shown here, covered with a ¼-in.-thick glass plate, and the excess mixture squeezed out in a small press with heavy metal platens. To prevent premature cooling and hardening of the mixture during this operation, the mold, glass cover plate, and press platens were preheated to 160° C, and the transfer and pressing were effected as quickly as possible. Self-release of the scintillator from the mold after cooling and contracting was aided by treatment of both mold and cover glass with a mold-release agent, Dow Corning 20.*

The resulting scintillator disk was backed with aluminum foil on one side to increase the light output from the opposite side, and the whole wrapped in Saran film for protection against atmospheric moisture. A transparent multipurpose type adhesive, such as Cello-stick was used to improve optical contact between the Saran film and the scintillator surface. Scintillators prepared in this way were kept in a dessicator while not in use because of the hygroscopic nature of the boron plastic component. Large flat sheets of this scintillator have been made this way.

Using HBO_2. *The preceding method was also followed with HBO_2, except that the operating temperature was kept at about 210° C instead of 160° C. It was difficult thoroughly to mix the ZnS(Ag) with the molten HBO_2, because of the higher viscosity of this boron compound. One way to improve mixing of these two materials is to reduce the HBO_2 to a 68-mesh (or smaller) powder and mix with the ZnS(Ag) powder prior to heating. A second and more reproducible method was to put the previously mixed ZnS(Ag) and HBO_2 powders into a mold to overflowing, cover the mold with a thick glass plate, and place in a heated press. Press temperature could be as low as 170° C.*

FIG. 1. Cell used for electron irradiation

Radiation Stability of Polyphenyls

How organic compounds will bear up under irradiation is crucial to the future of organic-moderated reactors. Experiments with polyphenyls prove *p*-terphenyl best. Mixtures tend to be as stable as their most stable component

By EUGENE L. COLICHMAN and REINHARD H. J. GERCKE
Atomics International Division, North American Aviation, Inc., Canoga Park, California

SERIOUS CONSIDERATION is being given to certain aromatic hydrocarbons as coolants and moderators for nuclear reactors. We have studied the thermal and radiation stability of some of the most promising organic materials as a basis for engineering tests of this new reactor concept.

After exposing samples to radiation, we have determined the evolution of gas by the three terphenyl isomers as well as biphenyl, *p*-quaterphenyl, and several mixtures of polyphenyl compounds. Irradiations were primarily with 1-Mev electrons at 30, 275, and 350° C. The gas-evolution method, used to measure decomposition due to these irradiations, is more sensitive than "polymer" formation for studying differences in radiation stability among the various polyphenyls.*

Other irradiations were performed in a reactor and with high-energy gamma-rays.

Electron Irradiation

A Van de Graaff generator was used to irradiate 5-gm samples with 1-Mev electrons. Beam intensities were 15–20 μamp and dose (energy absorbed in sample) was 2.5–100 watt-hr/gm. Temperature control was ±3° C.

Cell. The irradiation cell (Fig. 1) had a 0.025-in. aluminum beam window that was replaced for each run. A soft-aluminum O-ring sealed the window leak-tight. An arm with a valve was attached to the cell for easy removal of gas formed during irradiation. The valve had a Teflon seat and was air-cooled during irradiation to prevent damage to the seat and gas leakage.

Irradiation. First 5 gm of the solid material to be irradiated was put in the cell. Next the aluminum window was sealed in place, and the cell tested for leaks with a helium leak detector. When leaktight the cell was flushed with helium and evacuated to a pressure of 0.01 mm Hg; then this was repeated twice again. This procedure removed traces of air and water from the solid sample. The effect of more severe outgassing was determined by evacuating the loaded cell for two weeks to a pressure of 10^{-5} mm Hg, the cell being loaded with powdered *p*-terphenyl. Upon irradiation of this sample, the same volume of gas was produced as when the cell was flushed and evacuated in the usual manner.

After irradiation in a Van de Graaff

Organic-Moderated Reactors Have These Advantages . . .

- *Low vapor pressures at temperatures up to at least 850° F*
- *Low activation of the coolant as contrasted with liquid metals*
- *Lower viscosity of coolant at operating temperatures than with liquid metals*
- *No hazardous chemical reactions between uranium or water and the coolant*
- *Negligible corrosion of ordinary low-cost construction materials*
- *Working fluid has low density and contracts on cooling*
- *Can be designed with negative temperature coefficient of reactivity*
- *High hydrogen density and low neutron absorption cross section result in good neutron economy (in close-packed lattices and small cores)*

. . . and These Disadvantages

- *Heat transfer inferior to water, requiring higher coolant flow*
- *Hydrocarbon slowly polymerizes under exposure to radiation*

Polyphenols Are Best Among Organics Because of Their . . .

- *Good thermal and radiation stability*
- *Relatively low vapor pressure*
- *Reasonably low toxicity*
- *Commercial availability*

* The polyphenyls used were Eastman Kodak white-label grade and were used without further purification.

generator, the cell was connected to a Toepler pump that transferred gas produced by irradiation from the cell to a buret for volume determination. The composition of the gas was determined to the nearest 0.1% by mass-spectrometry. Besides providing gas composition these analyses indicated the presence or absence of a leak in the system during irradiation; the experiment was rejected if nitrogen or air was found in the gas.

Dosimetry. The energy absorbed in samples irradiated with the Van de Graaff generator was measured by integrating the current in the dissipated beam. Correction was made for the fraction of the total beam striking the sample, based on extensive calibration runs made with an aluminum plug in place of the sample.

Solute analyses. High boiler-residue content of the irradiation-decomposed polyphenyl materials defined as "polymer" was determined in each by careful vacuum fractional microdistillation. Spectral analyses were used to correct both the distilled and nondistilled portions (*1*).

Electron-Irradiation Results

Decomposition is expressed in terms of G values, molecules of gas (G_{gas}) or polymer (G_{poly}) formed per 100 ev absorbed. For polyphenyls only trace quantities of compounds other than polymer and gaseous decomposition products are formed, so gas and polymer formation define the radiation damage of the materials. The gas-evolution method is considerably more sensitive for showing differences in stability.

The amount of material in the irradiated zone was 0.20 gm in each case. Total polyphenyl sample used for each experiment was 5 gm so that effect of extended integral radiation doses could be studied without completely decomposing the original polyphenyl material. G_{gas} values were calculated on basis of the integral of the specific dose (watt hr/gm) over the entire mixture, that is, the total dose to the 5-gm sample.

The decomposition data for irradiations carried out at 30° C are summarized in Table 1. These results are also shown in Fig. 2 where it is seen that G_{gas} varies with the total energy

"Polymer" is here defined as having five or more phenyl rings. G_{poly} values have been calculated on the basis of a composite average polymer made up of two terphenyl molecules (*2*).

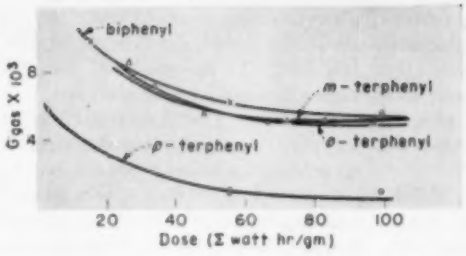


FIG. 2. G_{gas} as a function of dose for electron irradiation at 30° C

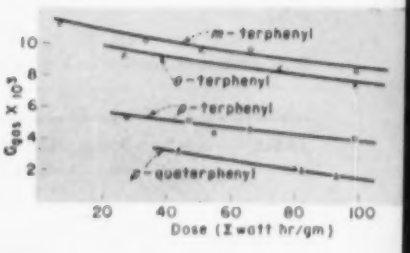


FIG. 3. G_{gas} as a function of dose for electron irradiation at 350° C

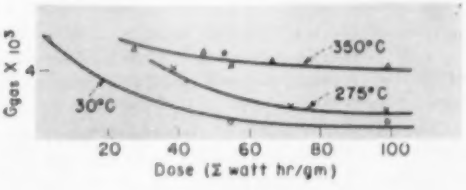


FIG. 4. G_{gas} as a function of dose for electron irradiation of p-terphenyl at three temperatures

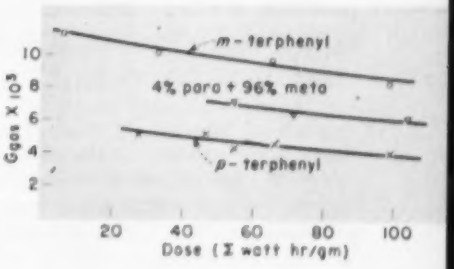


FIG. 5. Behavior of mixtures is shown here. Addition of only 4% p-terphenyl radically improves radiation stability at 350° C

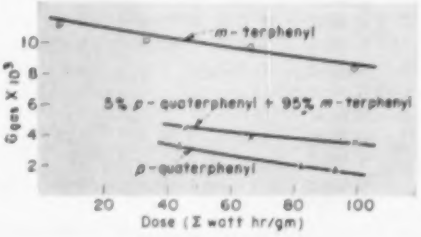


FIG. 6. Behavior of p-quaterphenyl m-terphenyl mixture is similar to that in Fig. 5. Irradiation temperature, 350° C

absorbed. At 30° C, *o*- and *m*-terphenyl are about equal in stability whereas *p*-terphenyl is significantly more stable than the other two. Biphenyl, which was irradiated also, is seen to be about as radiation stable as *o*- and *m*-terphenyl at 30° C.

The results of irradiations at 350° C are summarized in Table 2. In Fig. 3 the G_{gas} values are seen to decrease with dose in the same manner as for the 30° C irradiations. The *p*-terphenyl is the most stable terphenyl isomer, but *p*-quaterphenyl is more stable than *p*-terphenyl.

The effect on G_{gas} of varying the temperature is shown in Fig. 4, *p*-terphenyl serving as an example. G_{gas} is shown for three temperatures: 30, 275, and 350° C. As expected, the G_{gas} values increase with temperature.

Mixtures. The stability of some polyphenyl mixtures was determined. A mixture consisting of 4.0 wt % *p*-terphenyl and 96.0 wt % *m*-terphenyl was irradiated at 350° C to several doses. The G_{gas} values of this mixture lie (Fig. 5) about midway between those of the two pure components, being much more stable than expected if G_{gas} were an additive property. This increase in the stability of *m*-terphenyl, obtained by adding a small quantity of *p*-terphenyl, is accompanied by only a small increase in the melting point of *m*-terphenyl (see Table 3).

Another mixture containing 5 wt % *p*-quaterphenyl and 95 wt % *m*-terphenyl was also irradiated at 350° C. Figure 6 shows that the G_{gas} values of this mixture approach those of the pure *p*-quaterphenyl.

Thus adding a bit of a more radiation-stable polyphenyl to a less-stable polyphenyl yields a mixture approaching the stability of the more stable substance. The low melting point of the two mixtures tried (approaching pure *m*-terphenyl) and their high radiation stability suggest the advantage of using such mixtures as reactor coolants.

TABLE 1—Electron Irradiation of Polyphenyls at 30° C

Material	*Energy input (watt-hr/gm)*	*Gas yield (moles × 10⁵)*	G_{gas}	G_{poly}	*Gas composition (% by volume)*							
					H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_8	*Benzene*	*Undefined*
o-terphenyl	26.0	7.5	0.0085									
	47.5	9.2	0.0056		94.5	3.9	1.0			0.4		0.2
	71.5	12.9	0.0052	0.049	95.6	3.0	1.0			0.4		0.0
	97.0	16.6	0.0049	0.055	94.2	4.2	1.0			0.6		0.0
m-terphenyl	33.0	8.1	0.0071	0.055	85.0	7.0	4.0			3.0	0.3	0.7
	66.0	11.7	0.0051	0.041	87.6	6.0	3.0			2.0		1.4
	82.0	14.8	0.0052		88.0	6.8	3.0			1.8	0.1	0.4
p-terphenyl	2.7	0.55	0.0058									
	55.0	2.09	0.0011									
	55.0	1.71	0.0009	0.065								
	99.0	3.42	0.0010	0.038	92.2	2.9	0.4		0.9		0.3	3.3
Biphenyl	15.0	5.08	0.0098		97.5	1.2	0.6				0.3	0.4
	55.0	11.8	0.0062		98.0	1.5	0.4				0.1	0.0
	99.0	18.2	0.0053									

TABLE 2—Electron Irradiation of Polyphenyls at 350° C

Material	*Energy input (watt-hr/gm)*	*Gas yield (moles × 10⁵)*	G_{gas}	G_{poly}	*Gas composition (% by volume)*							
					H_2	CH_4	C_2H_6	C_2H_4	C_2H_2	C_3H_8	*Benzene*	*Undefined*
o-terphenyl	26.5	8.5	0.0093	0.079	93.4	3.0	2.0	0.5	0.5		0.6	0.0
	50.5	16.9	0.0097									
	75.0	21.8	0.0084									
	99.0	25.3	0.0074	0.063	92.7	3.9	1.2		1.0	0.2	0.2	0.8
m-terphenyl	6.0	2.35	0.0113	0.032	81.5	7.3	3.6		3.2	3.2		1.2
	33.0	11.6	0.0102	0.063	77.0	10.4	4.8		1.0	4.4	1.7	0.7
	66.0	22.1	0.0097									
	99.0	28.5	0.0083	0.038	82.0	10.1	4.7			2.5	0.3	0.4
p-terphenyl	27.0	4.95	0.0053	0.072	87.8	5.6	3.0		2.5	0.6		0.5
	46.5	8.22	0.0051	0.087								
	55.0	8.20	0.0043									
	66.0	10.5	0.0046	0.044								
	99.0	13.8	0.0040	0.055	86.1	5.3	2.0	1.2	2.3	0.7	0.5	1.9
p-quaterphenyl	43.0	4.77	0.0032									
	82.5	5.70	0.0020		82.8	10.4	1.9	0.5	0.5	0.6	3.1	0.2
	93.0	5.15	0.0016									

For all materials studied, the stability, as reflected in G_{gas}, increases with increasing dose—leveling off to a nearly constant value at higher doses. It appears that the decomposition products formed (presumably higher polyphenyls) increase (up to some equilibrium value) the stability of the parent compound. These results agree qualitatively with the higher stability of *p*-terphenyl–*m*-terphenyl and *p*-quaterphenyl–*m*-terphenyl mixtures.

Mechanism. A plausible explanation for the enhanced radiation stability might be that in a mixture the polyphenyl compound, which fluoresces at the lower energy level (longer wave length) and emits a higher intensity of fluorescent energy, will thereby protect less stable compounds from radiation decomposition by re-emitting considerable quantities of incident radiation as photons. Energy-transfer mechanisms in mixtures of fluorescent organic compounds have been investigated (*3*). *P*-terphenyl in solution showed the greatest fluorescent intensity of all organic solutes investigated (*4*). In keeping with the above proposed theory, this mechanism explains why small quantities of *p*-terphenyl enhanced the radiation stability of *m*-terphenyl in the present investigation.

A protective action operates in mixtures of cyclohexene and benzene (*5*). It appears that because of ionization and excitation energy transfers, the primary chemical process occurring in a mixture tends to be characteristic of the component of lower ionization potential. A possible mechanism for such protective action, operative during radiolysis, has been considered (*6*).

The composition of the gas produced by irradiation is predominantly hydrogen (see Tables 1 and 2) with smaller quantities of methane and ethane, and in some cases propane. Benzene is only present in trace quantities. No significant difference in gas composition seems to exist among the polyphenyl materials studied.

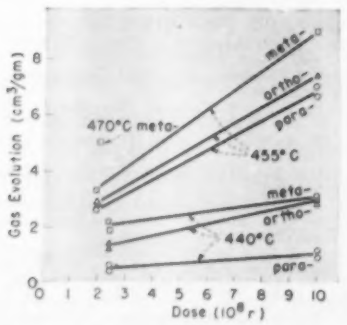


FIG. 7. Gas evolution after high-temperature gamma-ray irradiation

TABLE 3—G_{gas} for Polyphenyl Mixtures

Material	*Melting point* (°C)	G_{gas}*
m-terphenyl	85.6–86.0	0.0085
4.0% *p*- +96.0% *m*-terphenyl	110–111	0.0061
p-terphenyl	212.6–213	0.0039
5.0% *p*-quaterphenyl +95.0% *m*-terphenyl	—	0.0033
p-quaterphenyl	318–318.5	0.0014

* Dose = 100 watt hr/gm; temperature = 350° C.

TABLE 4—In-Pile Decomposition of Terphenyls*

Material	*Polymer produced* (wt %)	*Gas evolution* (cm^3/gm)
o-terphenyl	38.3 ± 1.0	2.04 ± 0.05
m-terphenyl	32.6 ± 0.9	1.35 ± 0.04
p-terphenyl	25.4 ± 0.7	0.38 ± 0.01
4% *p*-, +96% *m*-terphenyl	33.9 ± 0.9	0.66 ± 0.02

* Exposed in VH-3 hole, MTR. Integrated fluxes were: thermal neutrons (based on foil measurements) = 1.0×10^{19} n/cm²; fast (>1 Mev) neutrons (based on foil measurements), = 1.53×10^{17} n/cm²; gamma-rays (based on graphite heating), = 30 watt hr/gm.

Polymer fraction. Preliminary work has indicated that the polymer fraction may contain several individual species. The presence of biphenyl and quaterphenyl are not indicated. The polymer product is comprised of compounds with five and six phenyl groups as well as smaller quantities of compounds of higher molecular weight. The polymer product has not yet been completely analyzed. Therefore, elucidation of the complete radiation-decomposition mechanism of the terphenyl is not possible at this time.

On the basis of the G_{poly} and G_{gas} values, it appears that net (exclusive of recombinations) bond cleavages between phenyl rings occur 5–10 times as frequently as rupture of hydrogen atoms from ring carbon atoms.* The absence of significant quantities of short-chain aliphatic hydrocarbons indicates that phenyl rings seldom rupture.

* W. Wild (AERE, Harwell), personal communication, feels that gas yields indicate little regarding the number of original molecules altered during radiolyses because of subsequent substitution reactions. Though the net gas yields reported here may not be truly indicative of the primary decomposition process, results are representative of practical usefulness of "stability."

Other Irradiations

In addition to the electron irradiations described, samples were exposed to gamma rays and mixed reactor radiations.

For in-pile irradiations, 15-gm samples were sealed in helium-blanketed aluminum capsules and exposed till the thermal-neutron dose was 10^{19} nvt. This took about 21 hr in the VH-3 hole at the MTR. Temperature was that of the ambient cooling water, ~30° C.

Gamma-ray irradiations were carried out in the MTR spent-fuel canal using 0.75-gm samples sealed in Vycor tubes evacuated to 0.015 mm Hg. An insulated sample holder and pencil-type heater permitted irradiation at 440–470° C. Doses were $2\text{–}10 \times 10^8$ r; dose rate was 2×10^6 r/hr.

Gas evolved in either irradiation procedure could be collected, measured, and analyzed with the aid of a special opening device and associated Toepler pump and buret.

Results. In-pile irradiations (summarized in Table 4) indicate that *p*-terphenyl is the most stable isomer; this agrees with the 1-Mev-electron irradiations. The addition of small quantities of *p*-terphenyl to *m*-terphenyl greatly enhances radiation sta-

TABLE 5—Electron-Irradiation G Values for Hydrocarbons

Compound	*Source of data*	G_{H_2}	G_{CH_4}	G_{C_2}	$G_{gas\ total}$
Toluene	Burton, et al*	0.13	0.0077	0.0043	0.132
p-terphenyl	This article†	0.0042	0.0003	0.0003	0.0047
Benzene	Burton, et al*	0.036	0.0012	0.022	0.059

* From Ref. (*5*), irradiations with 1.5-Mev electrons on liquid at room temperature.
† Irradiations with 1.0-Mev electrons on liquid at 350° C in this laboratory.

TABLE 6—Comparison of G Values*

G value	*Reactor*	*Electron*
G_{H_2}	0.16	0.13
G_{CH_4}	0.006	0.008
G_{C_2}	0.016	0.001
$G_{gas\ total}$	0.182	0.139

* Data are for toluene; from T. J. Sworski, M. Burton, *J. Am. Chem. Soc.*, **73**, 3790 (1951)

bility; this also was the case with electrons.

At the temperatures and dose rate used, thermal decomposition is more significant than radiolysis. The thermal and gamma-radiation decomposition data are given as gas evolution (Fig. 7) and polymer formation (Fig. 8). These results, as do those from electron and in-pile irradiations, indicate that *p*-terphenyl is the most stable.

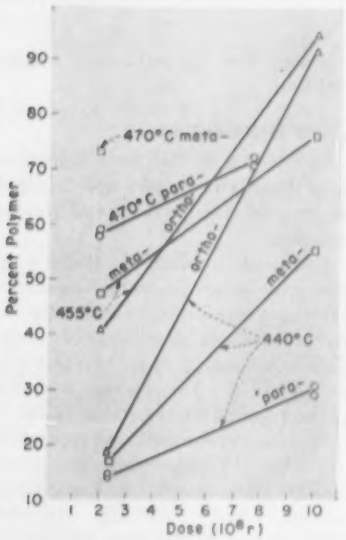


FIG. 8. Polymer formation after high-temperature gamma-ray irradiation

Source-Independence

Radiation damage in any organic material seems to be a function of the actual energy absorbed regardless of the nature of the radiation, as long as bond cleavage is independent of the type and intensity of ionizing radiation (*7*). Our data substantiate this.

Data given in Tables 1 and 2 show that radiation decomposition of the terphenyls yields hydrogen gas as the primary gaseous product. A comparison of the G values given in Table 5 shows that toluene, like the terphenyls, yields mainly hydrogen gas as the gaseous product, but that benzene yields substantial quantities of C_2 hydrocarbons as a result of ring rupture during radiolysis. When ring rupture is appreciable, as with benzene, no correspondence is found between reactor and electron irradiations, perhaps due to the influence of "knock-on" effects of heavier particles.

The data of Sworski and Burton (*5*) show equivalent effects for reactor and electron irradiation. Evidence in the case of the terphenyls is discussed below.

Radiation-damage studies by Sisman and Bopp (*8, 9*) on plastics and elastomers indicate equal change in physical properties of polymeric materials for equivalent energy deposition regardless of the irradiating particle.

Calkins (*10*) reports that gamma rays, X-rays, electrons, beta rays, and slow neutrons produce damage by substantially the same mechanism in most organic compounds with equivalent damage for the same energy absorbed.

Calculations were made using the reactor-irradiation data (Table 4) at an incident dose of 10^{19} nvt (thermal neutrons) to show that each terphenyl sample encapsulated in aluminum absorbed 2.1 watts/gm for 21 hr (i.e., 44.1 watt-hr/gm). This total energy absorbed was evaluated from: slowing down of fast (>1 Mev) neutrons, slowing down of epithermal (<1 Mev) neutrons, absorption of incident gamma rays, and absorption of thermal neutrons in aluminum container walls.

The gas produced from the 10^{19}-nvt reactor irradiations (Table 4) has been converted to cm³ per ev absorbed on basis of an absorption of 44.1 watt-hr/gm. This volume of reactor-produced gas for each terphenyl isomer (Table 7) then is compared with that evolved from electron irradiations (Fig. 2) at the same total energy absorption. G_{gas} values used in these calculations were those obtained by interpolation from the graphs in Fig. 3 at a total energy-absorption value of 44.1 watt-hr/gm.

Table 7 shows that electron and reactor irradiations produce equal radiation decomposition effects (gas evolution) for equal absolute-energy absorption.

TABLE 7—Comparison of Terphenyl G Values

Terphenyl	*Gas produced (10^{-24} cm³/ev)*		*Ratio (electron/reactor)*
	*Electron**	*Reactor*	
Ortho-	2.1	2.0	1.05
Meta-	2.1	1.4	1.50
Para-	0.52	0.38	1.37

* Electron-irradiation G values are from Fig. 2 at dosage of 44.1 watt hr/gm, equivalent to energy absorbed by terphenyl during reactor irradiations to 10^{19} nvt.

BIBLIOGRAPHY

1. E. L. Colichman, R. F. Fish, G. O. Bjarke, *Anal. Chem.*, submitted
2. E. L. Colichman, R. F. Fish, *Ind. Eng. Chem.*, submitted
3. M. Furst, H. Kallman, *Phys. Rev.* **85**, 816 (1952); **89**, 912 (1953); **94**, 503 (1954)
4. H. Kallman, M. Furst, NUCLEONICS **8**, 32 (1951)
5. J. P. Manion, M. Burton, *J. Phys. Chem.* **56**, 560 (1952)
6. M. Burton, Mechanism of radiation chemical reactions in organic and aqua-organic systems, NP-3237, p. 17 (1950)
7. A. O. Allen, in "The Science and Engineering of Nuclear Power," vol. 2, ch. 13, p. 207 (Addison Wesley, Cambridge, Mass., 1948)
8. C. D. Bopp, O. Sisman, Radiation stability of plastics and elastomers, ORNL-1373 (1954)
9. O. Sisman, C. D. Bopp, "Physical properties of irradiated plastics," ORNL-928 (1951)
10. V. P. Calkins, NUCLEONICS **12**, No. 9, 9 (1954)

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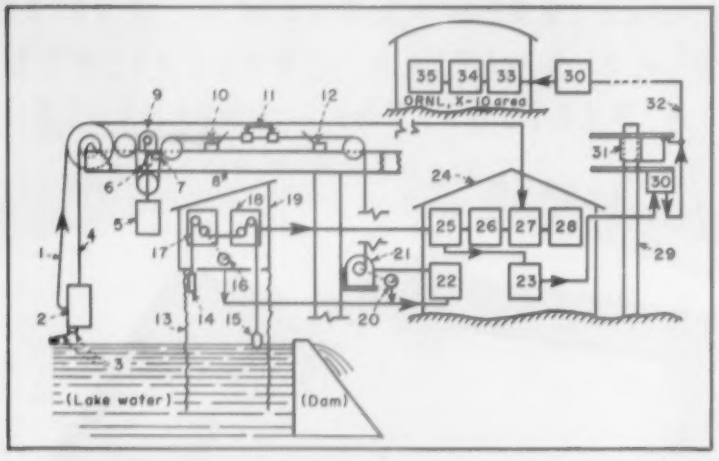

FIG. 1. Water-elevation and radioactivity-level monitoring system at White Oak Dam with telemetering to X-10 area. Water-elevation monitor uses counter-balanced float extending down into "stilling well" to prevent debris and waves from affecting measurements. System components are: 1—preamp cable from detector to meter (27), 2—radiation detector, 3—microswitch with cork float for safety mechanism, 4—$\frac{5}{32}$-in. stainless-steel cable supporting detector, 5—detector counterweight for safety mechanism, 6—solenoid for safety mechanism, 7—limit switch for safety mechanism, 8—boom assembly supporting detector, 9—motor for safety mechanism, 10—limit switch in servomechanism, 11—limit switch trippers for servomechanism, 12—limit switch in servomechanism, 13—stilling well, 14—float counterweight, 15—float for water-level recorder, 16—Helipot in servomechanism, 17—water-elevation monitor, 18—water-elevation metameter transmitter, 19—gage house, 20—Helipot in servomechanism, 21—motor in servomechanism, 22—servomechanism for controlling detector elevation; 23—carrier-current rf transmitter, 24—instrument shack, 25—commutator, 26—gamma-radiation metameter transmitter, 27—counting-rate meter, 28—strip-chart recorder, 29—telephone pole, 30—tuned rf filters, 31—powerline transformer, 32—a-c power line to X-10, 33—carrier-current rf receiver, 34—metameter receiver, 35—alarm system

System Continuously Records Water Level and Contamination

By FORD KALIL* and J. M. GARNER, Jr.
Health Physics Division
Oak Ridge National Laboratory, Oak Ridge, Tennessee

The problem of continuously monitoring water supplies for radioactive contamination is growing in importance because of the increasing use of nuclear reactors and radioactive materials in research laboratories and the resulting increase of radioactive waste disposal in neighboring lakes or streams. Investigators have reported various methods of water monitoring (*1–6*).

Our purpose was to develop an outdoor water monitor that would not be affected by debris, algae, or weather conditions and one that would continuously measure the gamma concentration of contaminated water supplies, such as lakes or streams. It is desirable to also record the water elevation and have a continuous record of these data available at a central control station with an alarm to call attention when either the radioactivity or water elevation levels exceed a predetermined value. McKay and Walton (*7*) have discussed safety criteria in radioactive-water monitoring, based on reported maximum permissible concentrations of radioisotopes in water and other criteria (*8, 9*).

The present system consists of:

1. A gamma-radiation monitor for continuously measuring the gamma-radiation dose of lakes or streams into which radioactive wastes are discharged.
2. A continuous water-elevation recorder.
3. A telemetering system for transmitting the water elevation and the radioactivity levels to a central station.

The system, shown in Fig. 1, was installed at White Oak Dam in 1952 (*2*) to continuously monitor the water discharged from White Oak Lake, which is contaminated with radioactive wastes from the Oak Ridge National Laboratory. The water elevation and the radioactivity levels are continuously transmitted to and recorded at the Oak Ridge National Laboratory, which is several miles from the dam.

Radiation-Level Monitor

Detector. The detector is suspended a constant distance over the surface of the water by means of a boom and servomechanism. The water-tight detector utilizes an anthracene scintillation crystal, a Lucite light piper, a 5819 photomultiplier tube, and a preamplifier, which are built into a cylindrical lead pig with 2-in. wall thickness. Because of the lead pig and a beta shield, the scintillator responds only to gamma rays from the water below the detector. The detector is unidirectional so that it does not detect the radioactivity contaminating the lake banks, since this activity would not be discharged from the lake.

Thermistors in the photomultiplier cathode circuit regulate the photomultiplier dark current and make the detector insensitive to temperature variations of 0–50° C (*10*).

Counting-rate meter. The counting-rate meter (*11*) is linear and accurate to within ±1%. A built-in calibration circuit permits calibration against the 3,600-cpm a-c power.

The ratemeter holds its calibration to within about ±3% over a period of several months of continuous operation. The long time constant of the ratemeter permits an alarm on sustained high levels of radioactivity while disregarding momentary peak levels due to passing debris and algae. In addition, a wide range of scales allows measuring both low background and high

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radiation levels as in the case of a "spill."

Servomechanism. The servomechanism automatically controls the distance between the detector and the water elevations to within $\pm \frac{3}{64}$ in.

Briefly, the servo operates as follows (numbers refer to Fig. 1): The sensing elements (16 and 20) are helipots ganged to the water-elevation recorder and the shaft of the heavy-duty motor (21), which regulates the detector elevation. The resistance from the sliding contacts of the helipots to ground is directly proportional to the water and detector elevations. A d-c potential is applied across the helipots so that any variation in either the water or detector elevation produces a variation in potential between the two sliding contacts of the helipots. This change in potential is detected by the Brown amplifier, which energizes the Brown motor (22). The Brown motor in turn energizes the heavy-duty motor (21) by means of a cam to rotate in a direction to correct for any changes in water or detector elevations. The motor (21) was geared down to a very slow speed because the water elevation changes very slowly. The detector elevation could also be controlled manually by means of variable resistance in series with the helipots. The limit switches (10 and 12) are tripped by the bushings (11) when the detector elevation reaches either its preset minimum or maximum.

Safety mechanism. The safety mechanism protects the detector from radioactive contamination by preventing immersion in the water.

The safety mechanism is put into operation by a momentary contact start switch that energizes a motor (9). This motor raises the counterweight (5) into position. When in position the weight trips the limit switch (7) to de-energize the motor and energize the solenoid (6), which "latches onto" the counterweight to hold it in position. In case of all types of failures other than power-line failures, the solenoid would be de-energized by the microswitch with the cork float on the bottom of the detector releasing the counterweight, which is heavy enough to raise the detector out of danger to its maximum elevation. The solenoid, which is energized by 110 volts, a-c, would be directly de-energized in case of power-line failures.

Telemetering System

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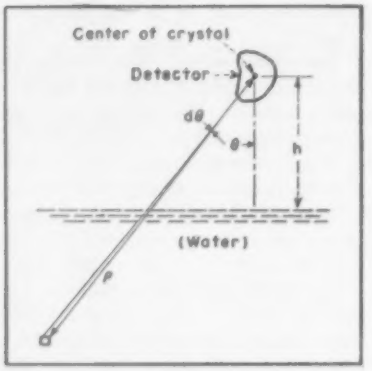

FIG. 2. Geometry for detector calibration

its relative simplicity, and because it obviates the need for a radiooperator's license (*12*). The economics and availability of commercial equipment were also taken into consideration.

Metameter transmitters (*12*) are used to alternately pulse-width modulate an rf transmitter, which transmits the signals over the existing power lines to a central station where the information is received by an rf receiver. Two metameter transmitters are used—one for the water elevation and one for the radioactivity level. A commutator with a complete operating cycle of 10 min commutates the signals from the water-elevation and radioactivity-level metameter transmitters in 3- and 7-min intervals, respectively. Thus, there is no difficulty in discriminating between the two signals at the receiving end.

The pulse-width modulation is achieved by keying the rf transmitter with the mercury switches of the metameter transmitters. The pulse width is directly proportional to the information being transmitted. The avc voltage of the receiver energizes a relay for the time of the pulse width. The pulse-width times are of the order of seconds. The relay used operates properly with avc voltages of 12–176 volts. Hence, the signal strength could vary considerably without affecting the results. The relay contacts, which are synchronous with the mercury switches, simulate a direct-wire connection between the metameter transmitters and the metameter receiver. The metameter receiver demodulates the signals (*12*) and records the water elevation and radioactivity levels on a strip-chart recorder.

The alarm system is a bell that rings when the strip-chart recorder at the receiving end reaches a full-scale reading.

Chart recordings are also made of the water elevation and the radioactivity levels at the transmitting end as a continuous check of the telemetering system. A comparison of the chart recordings from both the transmitting and receiving ends over a period of several months showed that the telemetering system, *per se*, was accurate to within ±5%. This does not include instrumental errors involved in measuring the water elevation and radioactivity levels.

An auxiliary standby rf transmitter and an auxiliary standby rf receiver were installed at the transmitting and receiving ends to be used in cases of emergency.

Calibration

In the calibration procedure, we define $\Phi(E)$ as the number of photons per second of energy E that are counted by the radiation monitor. Referring to Fig. 2

$$\Phi(E) = M(E)\epsilon(E)A \int_{h/\cos\Theta}^{\infty} \int_0^{\pi/2} \frac{e^{-[\rho-(h/\cos\Theta)]\mu(E)}}{4\pi\rho^2} f(\Theta)\, d\rho\, 2\pi\rho^2 \sin\Theta\, d\Theta$$

$$= \frac{M(E)\epsilon(E)A}{\mu(E)} \left[\frac{1}{2}\int_0^{\pi/2} \sin\Theta\, f(\Theta)\, d\Theta\right] \quad (1)$$

where $M(E)$ = number of photons per second of energy E per cubic centimeter water volume, $\epsilon(E)$ = radiation-monitor counting efficiency, A = sensitive area of scintillating crystal = 11.4 cm², $\mu(E)$ = true coefficient of absorption of water in cm^{-1} for gamma rays of energy E (*13*), $f(\Theta)$ = directional characteristic of the detector, and ρ, h, and Θ, defined in Fig. 2, are in units of centimeters and degrees.

$$G(E) = \frac{1}{2}\int_0^{\pi/2} \sin\Theta\, f(\Theta)\, d\Theta \quad (2)$$

where $G(E)$ may be referred to as the "geometry factor" since $G(E)$ is essentially a measure of the detector geometry as a function of energy.

Therefore, to calibrate the radiation monitor, it was necessary to determine $\epsilon(E)$ and $G(E)$. The efficiency $\epsilon(E)$ of the radiation monitor was measured with essentially collimated gamma radiations from the radioisotopes I^{131}, Au^{198}, Rh^{106}, Cs^{137}, Nb^{95}, Co^{60}, and Na^{24}. The radiation-monitor efficiency, measured to be 0.23 for these isotopes, was very nearly constant. The function $f(\Theta)$ was then measured by rotating essentially point sources of these radioisotopes about an axis through the cen-

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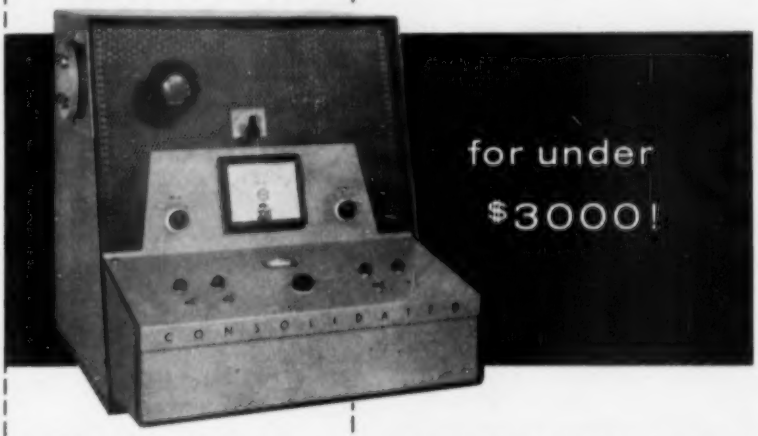

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ter of the detector crystal and perpendicular to the longitudinal axis of the cylindrical detector. As would be expected, the function $f(\Theta)$ varied for the different isotopes because of the difference in the shielding effect of the detector lead shield for different energies. It was found that

$$G(E)\ \epsilon(E)/\mu(E) = 7.7E \qquad (3)$$

where E is the photon energy in Mev. The values $[G(E)\ \epsilon(E)]/\mu(E)$ did not vary from this relationship by more than $\pm 10\%$ for the isotopes used. Hence

$$\Phi(E) = 7.7\ M(E)E \qquad (4)$$

for average photon energies covering the same range as the average photon energies of the isotopes used, from about 0.34 to 2.07 Mev.

It has been shown theoretically (*14*) that

$$M(E) = 14.43\ I(E)/E \qquad (5)$$

where $I(E)$ is the gamma-ray immersion dose rate in mr/hr. Hence, the counting-rate measurement of the radiation monitor is directly proportional to the gamma-ray immersion dose rate in mr/hr, i.e.

$$I = 9\Phi \times 10^{-3} = 1.5N \times 10^{-4} \qquad (6)$$

where N = radiation-monitor counting rate in counts/min. Perhaps the constant appearing in Eq. 5 ought to be checked experimentally.

From a periodic check of the ratio of the number of beta particles per gamma photon in the contaminated water (ξ), the beta contamination can also be roughly evaluated from

$$\bar{M} \simeq 2.2\xi\left(\frac{\bar{N}}{\bar{E}}\right) \times 10^{-3} \qquad (7)$$

where M, $\bar{N}$, and $\bar{E}$ are the average values of the number of betas per second per cm³ of water volume, the radiation-monitor counting rate in cpm, and the photon energy in Mev, respectively, over a given period of time. In addition, from the continuous water-elevation measurements and the gate setting in the weir of the dam, the amount of gamma and beta activity discharged from the lake can be evaluated.

* * *

This work was done under the auspices of the U. S. Atomic Energy Commission.

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BIBLIOGRAPHY

1. J. B. Hursh, S. Zizzo, A. H. Dahl, Nucleonics **9**, No. 5, C-16 (1951)
2. "Instrument Research and Development," ORNL-1389 (1952)
3. W. M. Hurst, "Monitoring of Liquids for Radioactivity," ORNL-1155 (1952)
4. A. H. Emmons, R. A. Landerdale, Nucleonics **10**, No. 6, 22 (1952)
5. J. W. Healy, Nucleonics **10**, No. 10, 14 (1952)
6. W. R. Loosemore, Nucleonics **11**, No. 10, 36 (1953)
7. H. A. C. McKay, G. N. Walton, Nucleonics **5**, No. 2, 12 (1949)
8. K. Z. Morgan, *Acta Radiol.* **41**, 30 (1954)
9. National Bureau of Standards Handbook 52 (1953)
10. H. N. Wilson, Oak Ridge National Laboratory, private correspondence
11. F. M. Glass, Oak Ridge National Laboratory, private correspondence
12. P. A. Borden, G. M. Thynell, "Principles and Methods of Telemetering" (Reinhold Publishing Corp., New York, 1948)
13. W. S. Snyder, J. L. Powell, Absorption of gamma rays, ORNL-421 (1950)
14. K. Z. Morgan, Oak Ridge National Laboratory, private correspondence

Autoradiography in the Study of Surface Phenomena

By B. VERKERK
Philips Research Laboratories
Eindhoven, Netherlands

Scattered radiation from the interior of specimens is one of the limitations on autoradiographic resolution. The best definition is obtainable when the activity is confined to the surface. This article describes the technique used here for making surface autoradiographs of metal specimens.

Technique

We have found the floating technique with the Kodak autoradiographic plate (*1*) very convenient.

In the case of short-lived isotopes, whose activities were so high that an image was produced within a half hour, a warm-air blast was necessary to dry the emulsions rapidly. If dust accumulation is prevented, the air stream is helpful in firmly pressing the emulsion onto the specimen. After the exposure, the emulsion was carefully stripped from the sample and floated (emulsion side up) onto a microscope slide previously covered with a layer of gelatin. After complete drying, the emulsion was processed in Kodak D-19 developer without danger of the emulsion floating off the glass plate.

When working with metallic samples, the formation of artifacts, probably due to contact with the wet emulsion, necessitated the use of a protective film in every case. Because resolution loss is high when the sample is separated only a few microns from the emulsion (*2*), the films have to be very thin. Satisfactory films were made by dipping the specimen into a 0.5% solution of Formvar in dichloroethylene, then slowly taking it out with the surface of interest in a vertical position and allowing the solution to drain.

The wet-emulsion technique of Gomberg (*3*) was tried to further improve resolution. However, the films proved to be nonprotective because silver immediately deposited from the bath onto the specimen. The slightest imperfection of the protecting film causes a silver deposit that keeps growing under the film. We could not test the films Gomberg advised using.

Sample Preparation

Cahn (*4*) suggested making a very thin layer of activity by exchange between metals and their ions in solution.

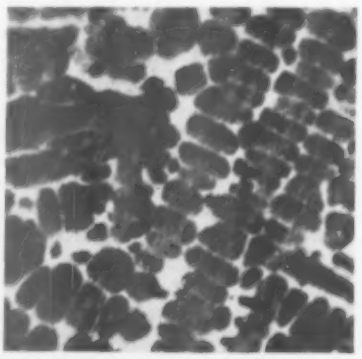


FIG. 1. Autoradiograph of 80% Cu-20% Ag alloy. Surface activated by Cu^{64} exchange from solution. (Magnification 100 ×)

Many metals rapidly undergo such an exchange (*5*), which ranges between a few and several thousand atomic layers, depending on the metal and a number of variables, such as composition of the solution, pretreatment of the surface, time, and temperature.

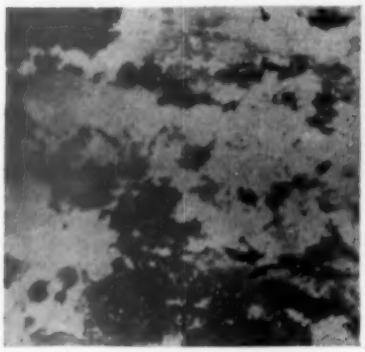
According to Haissinsky (*5*), copper shows a very fast and strong exchange. Copper-64 in a bromide solution gave excellent results on a copper-silver alloy as shown in Fig. 1. The exchange was uniform on the copper phase, and the resolution is better than 3 microns.

A difficulty arises by the fact that for electrochemical reasons only the least noble component can be exchanged if one is to be certain of the place where the activity is deposited.

Westermark and Erwall (*6*) used the exchange of lead with Pb^{212} (thorium B). But we could not observe an exchange of Zn^{65} with zinc in brass—perhaps because it is present in the latter as a Hume-Rothery compound.

The possibilities of the method should be pursued further.

K-capture isotopes. It was observed that only a relatively small num-



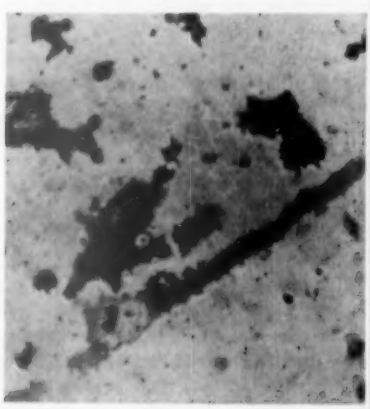


FIG. 2. Chlorine adsorbed on aluminum oxide film. Extended fields—physically adsorbed Cl; round spots—chemisorbed Cl. (Magnification 100 ×)

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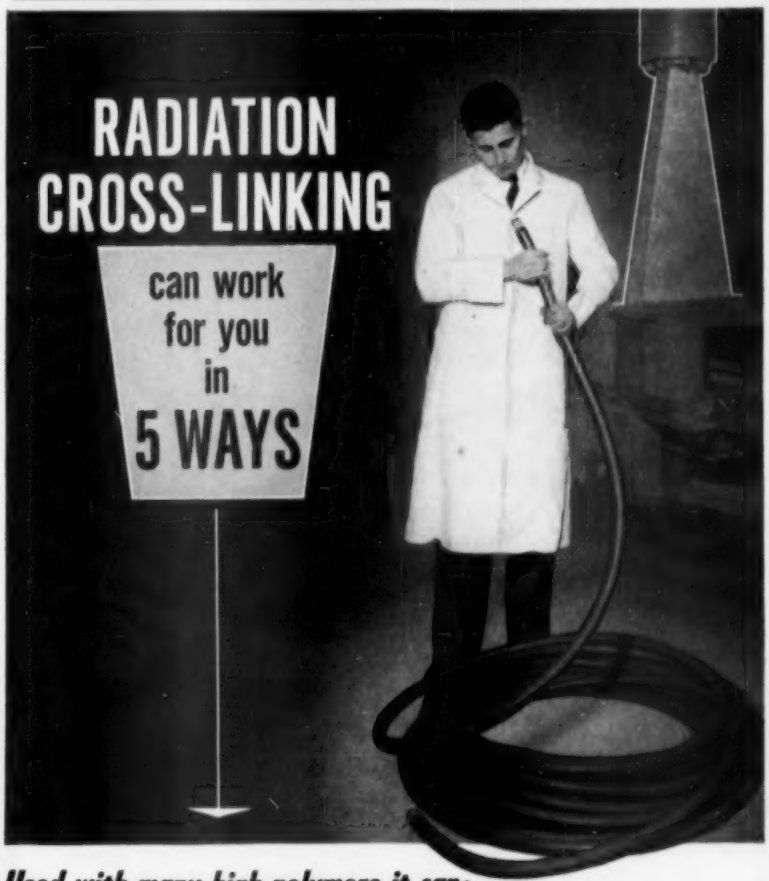

Used with many high polymers it can:

1. *Increase resistance to high temperatures*
2. *Improve electrical characteristics*
3. *Improve mechanical properties*
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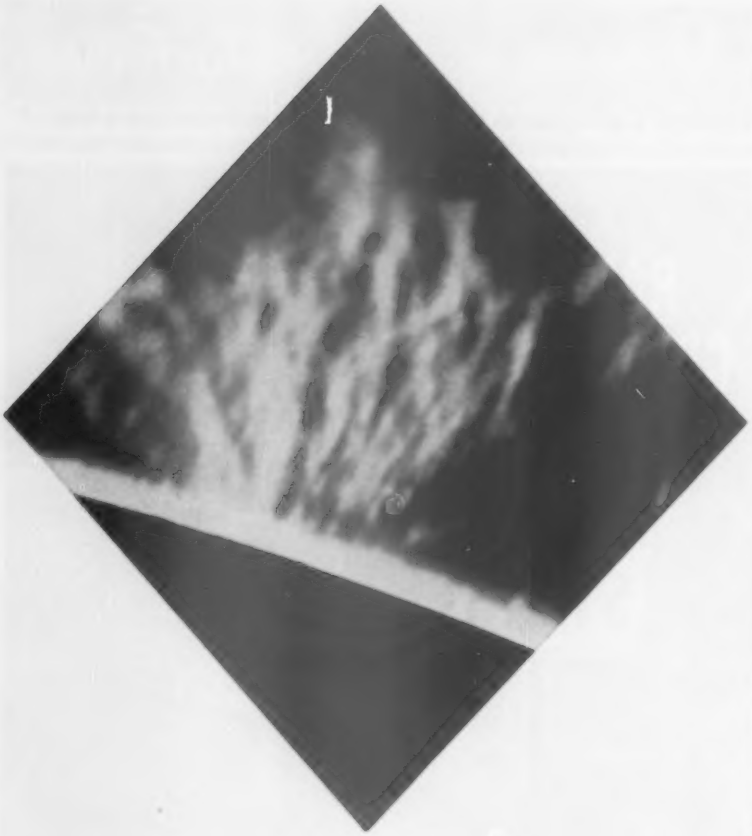

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ber of particles was needed to produce a dense autoradiograph with Cu^{64}. The value found was 9×10^7 disintegrations/cm², which compares favorably with 5.6×10^8 given by Herz (*1*) for I^{131} having nearly the same beta energy and using the same emulsion. Perhaps part of the difference was due to the absense of latent image fading as our experiments only took a short exposure time.

The high density was probably caused by the low-energy Auger electrons following K-capture, Cu^{64} decaying with 43% capture. The Kodak autoradiographic plate shows increasing sensitivity to particles with decreasing beta energy. Therefore K-capture isotopes of the common metals, such as Mn^{54}, Fe^{55}, Ni^{57}, Cu^{64}, and Zn^{65} will be particularly suited to produce photographic images.

An Application

As a further application of autoradiography, the influence of chlorine on semiconducting alumina layers was studied to determine the mechanism. The presence of small quantities of halogens, and notably chlorine, in electrolytic capacitors has a disastrous effect on the insulating properties of very thin layers of aluminum oxide (*7, 8*).

The chlorine was a mixture of Cl^{34} and Cl^{38} (respective half-lives of 32 and 37 min) produced in the Amsterdam cyclotron. To adsorb a sufficient activity on the surface to produce a visible autoradiograph in the short time available before complete decay, the initial activity in the solution had to be rather high—about 1 millicurie per experiment.

In a neutral chloride solution, without a potential applied to the oxide-covered aluminum, a very slight adsorption took place within 10 min—far too small to locate the chlorine by autoradiography. However when the oxide layer was made anodic in a chloride- or chlorate-containing electrolysis bath (10 mg Cl/liter), a current started to flow immediately, which increased steadily, ultimately causing a number of black pits in the oxide layer.

Part of the adsorbed chlorine was easily washed away with water but the other part was more tightly bound as the quantity on the surface remained nearly constant on rinsing for a half hour or more. The quantity of loosely attached chlorine decreased with rising temperature, indicating a physical adsorption, while the quantity of strongly

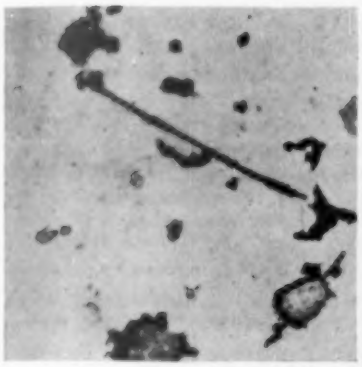

FIG. 3. Preferential adsorption of chlorine at surface cracks. At circular spots covering cracks, oxide layer is strongly attacked. (Magnification 100 ×)

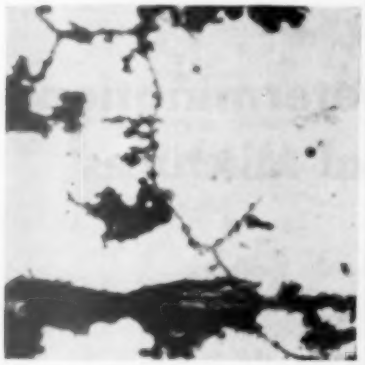

FIG. 4. Preferential adsorption of chlorine along grain boundaries of underlying recrystallized aluminum. (Magnification 100 ×)

bound halogen showed a positive temperature dependence, indicating some kind of chemisorption.

Autoradiographs were obtained of surfaces exposed to the chlorine attack and rinsed briefly to remove adhering solution and of surfaces rinsed so long that only the strongly bound chlorine was still present. A striking difference was found.

It appeared that the physical adsorption had taken place more or less evenly on extended parts of the surface. The total quantity of chlorine adsorbed in this way increased with the time of attack. The strongly bound halogen, however, was present on small isolated spots of a nearly circular form and very often on places where small cracks were present in the surface. Both types of adsorption are clearly visible in Fig. 2. A typical example of adsorption at cracks is shown in Fig. 3. A great number of similar but often much smaller spots were present on many radiographs.

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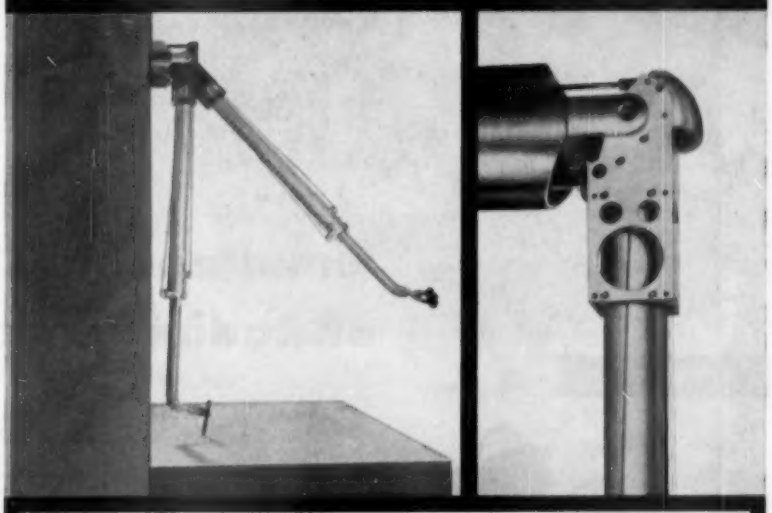

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present in the oxide layer or in the metal, autoradiographs were made of chlorine adsorbed on oxide formed on very pure aluminum that had been recrystallized to give very large crystals. An important part of the attack had taken place along grain boundaries of the underlying metal. This confirms the view that on cracks and along grain boundaries the oxide layer is weakest owing to existing stresses. Figure 4 is an example of attack along grain boundaries.

All the autoradiographs shown were magnified 100 times. Tests with much greater magnifications showed the resolution to be 2–3 microns.

The investigations are being continued with sheet metal of various purities, with oriented crystals to decide whether the physical adsorption depends on the crystal face, and with oxide layers prepared under different conditions.

BIBLIOGRAPHY

1. R. H. Herz, NUCLEONICS **9**, No. 3, 24 (1951)
2. I. Doniach, S. R. Pelc, *Brit. J. Radiol.* **23**, 184 (1950)
3. H. J. Gomberg, NUCLEONICS **9**, No. 4., 28 (1951)
4. R. W. Cahn, Proceedings of the Isotope Techniques Conference, Oxford, 1951. Vol. 2, p. 15 (1952)
5. M. Haissinsky, M. Cottin, B. Varjabedian, *J. chim. phys.* **45**, 212 (1948)
6. T. Westermark, L. G. Erwall, *Research* **4**, 290 (1951)
7. G. Muriset, *J. Electrochem. Soc.* **99**, 285 (1952)
8. F. Pavelka, *Kolloid Z.* **109**, 145 (1944)

Simultaneous Determination of Radiochemical Mixtures

By ALVIN S. BLUM
Radioisotope Service, Veterans Administration Hospital
Coral Gables, Florida

A rapid and simple method has been developed in this laboratory for counting the body electrolytes, sodium and potassium, simultaneously. It can be applied to the resolution of other mixtures of radiochemicals in anorganic or biological situations. The method uses a single gamma-sensitive detector plus "mathematical resolution." Complete chemical separation is not necessary—anything that will partition the elements differentially, e.g., added red cells or tissue slices, can accomplish differential counting.

Sodium and potassium are so closely related physiologically that it often is important to know the body content of each element at the same time. Several methods appear in the literature (*1–3*) for simultaneous determination of total body exchangeable sodium and potassium. In each method, measured amounts of Na^{24} and K^{42} are administered. After a suitable interval during which equilibrium is established (24–40 hr), a sample of plasma or urine is collected. The specific activity of each element (radioactive concentration divided by stable concentration) is found by a combination of counting and flame photometry. Then when the total activity of the isotope in the body is divided by the specific activity, the quotient is the total amount of exchangeable stable element in the body.

The difficulties in performing the measurements simultaneously are all related to the problem of differential counting of a mixture of these two radioelements, which have similar radioactive and chemical properties. The published methods involve either chemical separation or differential counting using two detectors, one sensitive to the gamma rays of both, the other more sensitive to the stronger beta rays of K^{42}.

Our method is based upon two facts: (a) At equilibrium, the specific activity of each element is the same in all body compartments. (b) In some body compartments, e.g., plasma, red cells, urine, the relative concentrations of the two elements differ, and these concentrations are easily measured photometrically.

The isotopes are administered in the usual fashion. At equilibrium a blood sample is drawn and a sample of recently excreted urine is collected. Aliquots of the injected doses of Na^{24} and K^{42} are counted in a gamma-sensitive system. Measured volumes of plasma and urine are counted. These urine and plasma samples are

then analyzed for Na and K concentrations on the flame photometer. (Hemolyzed red cells might be substituted for urine.)

The total counts of the two samples and their Na and K concentrations are applied to a special formula to get specific activities of Na and K. These specific activities are then applied to the usual formula for total body electrolyte.

Let p = plasma, c = urine, Na_p^{24} = radiosodium cpm in plasma, K_c^{42} = radiopotassium cpm in urine, Na_p = total sodium concentration in plasma, K_p = total potassium concentration in plasma, S_n = sodium specific activity, S_k = potassium specific activity, P = total plasma cpm, and C = total urine cpm. Then

$$P = Na_p^{24} + K_p^{42}$$
$$C = Na_c^{24} + K_c^{42}$$

We now have two equations in four unknowns. Since $S_n = Na_p^{24}/Na_p = Na_c^{24}/Na_c$, radioelement concentration (unknown) can be related to stable-element concentration (measured photometrically): $S_n = Na_p^{24}/Na_p$ or $Na_p^{24} = S_n Na_p$ and $K_c^{42} = S_k K_c$. Substituting

$$P = S_n Na_p + S_k K_p$$
$$C = S_n Na_c + S_k K_c$$

We now have two equations in two unknowns. Solving for specific activities

$$S_n = \frac{PK_c - CK_p}{Na_p K_c - Na_c K_p}$$

$$S_k = \frac{CNa_p - PNa_c}{K_c Na_p - K_p Na_c}$$

These specific activities (in cpm/milliequivalent) are used in the formula

[(cpm aliquot × dilution)
− (cpm electrolyte excreted × volume excreted)]/S_n or S_k
= milliequivalents exchangeable Na or K in body

The second term in the numerator can be easily evaluated when S_n and Na concentration of cumulative (24–40 hr) urine are known. It is usually less than 4% and may be disregarded.

BIBLIOGRAPHY

1. C. V. Robinson, *et al.* An improved method for simultaneous determination of exchangeable sodium and potassium, *J. Clin. Inv.* **34**, 134 (1955)
2. W. L. Arons, *et al.* The simultaneous measurement of exchangeable body sodium and potassium utilizing ion exchange chromatography, *J. Clin. Inv.* **33**, 1001 (1954)
3. A. H. James, *et al.* The simultaneous measurement of exchangeable sodium and potassium in man by isotope dilution, *Metabolism* **3**, 313 (1954)

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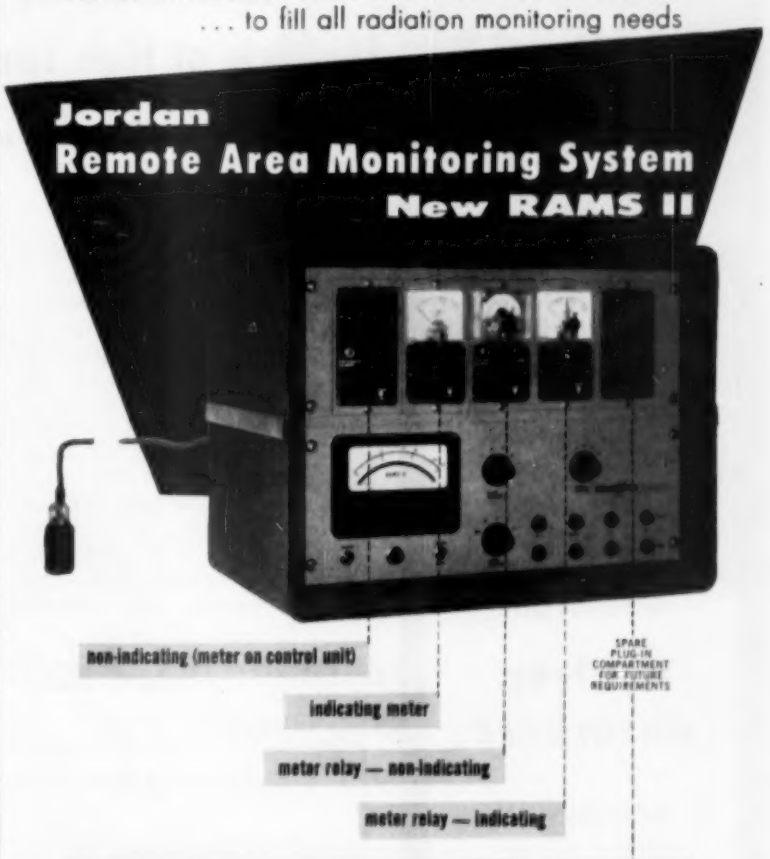

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Filter-Bomb Sampling Technique for Phase Equilibria at High Temperature, Pressure

By R. M. BIDWELL, W. R. WYKOFF, and B. J. THAMER
*Los Alamos Scientific Laboratory**
Los Alamos, New Mexico

For measuring solubility or more general phase studies, the compositions of a solid and a liquid phase in equilibrium can be calculated if the gross composition is known and if a portion of the liquid is removed and analyzed. At elevated temperatures and pressures, however, the separation and removal of a portion of liquid presents difficulties, especially since the separation should take place at as close to equilibrium conditions as possible.

Several reviews (*1–3*) have been published covering the many methods used for determining phase relationships under extreme conditions. In some of the most practical techniques (*4–6*), a sample of the solution is taken at equilibrium conditions into a sampling device built into the pressure vessel, or taken out very rapidly through a tube.

In many cases more accurate and reliable results are obtained by filtering the solution before sampling. In this way the possible carrying over of solid particles can be eliminated.

As with simple sampling, sampling with filtration must take place as nearly as possible at the equilibrium temperature and pressure of the experiment. If changes occur in solution before filtration, the experiment is valueless.

* Operated by the University of California for the U. S. Atomic Energy Commission.

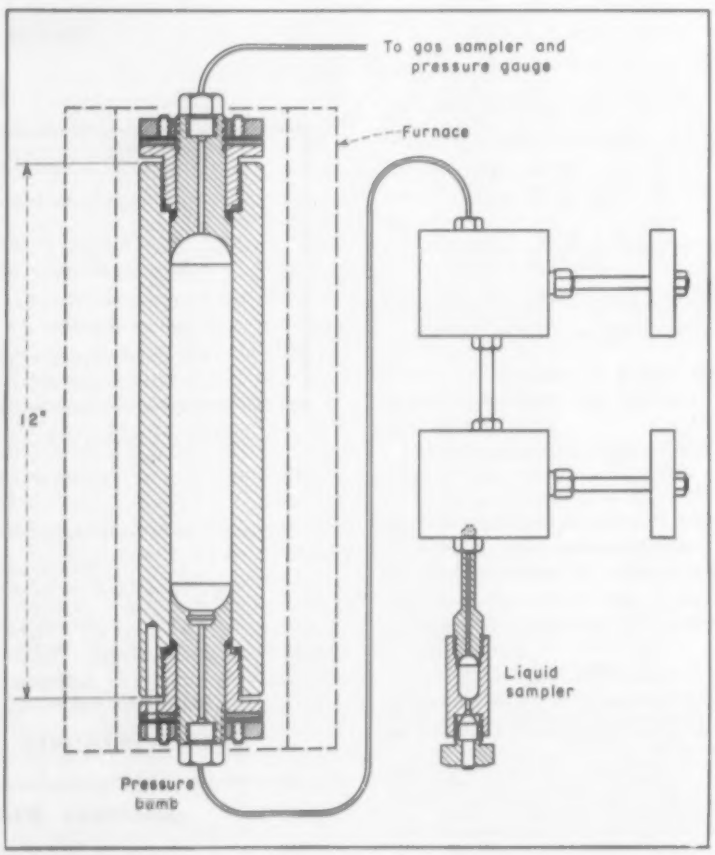

FIG. 1. Sampling assembly

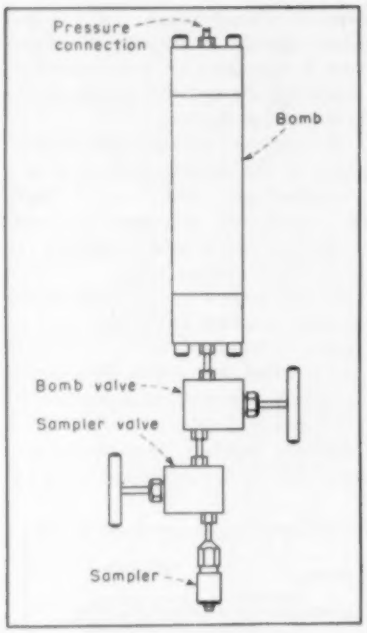

FIG. 2. Sampling assembly—close arrangement

To effect filtration with little or no disturbance of equilibrium, the internal-filter technique was developed by Tilden and Shenstone (*7*) and improved and modified by later investigators (*1, 8–11*).

Sampling and filtration techniques were later combined in sampling through a filter inside the high-pressure vessel. This was done either by a filter in the wall of the bomb (*12*) or by a "filter stick," a tube inserted into the vessel and having a sintered metal or ceramic filter on its end (*1, 13*). In either case a tube led to a small external sample container.

Although filter sticks are used at Los Alamos Scientific Laboratory, they have the disadvantage of being comparatively frail, with the possibility of breaking with continued agitation. They would also be difficult to use when a quantity of bulky solid is initially present in the bomb. A filter in the bomb wall is therefore used almost exclusively at this laboratory for high-pressure phase separation.

The unique feature of the apparatus is a machined filter plug pressed permanently into a recess inside the lower cap of the bomb (Figs. 1 and 4).

The filters are made from platinum particles, 40–325 mesh, pressed by standard powder metallurgical techniques to pellets of about 50% density. The particles, somewhat porous them-

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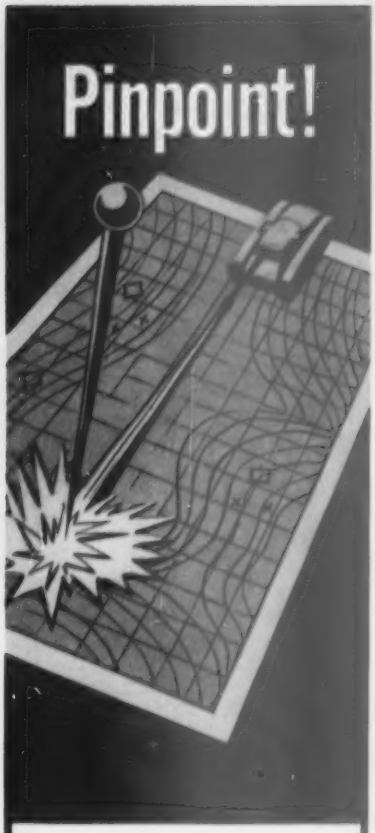

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selves, are made by decomposition of platinum chloride.

Stainless-steel filters have been used for neutral aqueous and nitric acid solutions, but platinum is now used exclusively because of its resistance to almost all corrosive media.

Apparatus

The fundamental experimental assembly for separating phases at high temperatures and pressures is shown in Figs. 1 and 2.

A high-pressure bomb is suspended in a resistance furnace (Fig. 1). It is connected through a length of hypodermic-needle tubing and two valves to a liquid sampler. A second capillary tube leads from the top of the bomb to a pressure gage, and to a gas-phase sampler if desired. Temperature is measured by a thermocouple inserted in a well drilled longitudinally in the wall of the bomb.

If the liquid sampled may be corrosive to the capillary tubing, or if a precipitate may form, a short length of $\frac{1}{16}$-in.-bore stainless-steel high-pressure tubing is used in place of the hypodermic tubing (Fig. 2). This technique lacks a safety feature of the distant sampling, but in any case no failure of a bomb or its connectors has occurred with either type during sampling. An alternative method for corrosive materials is to lead in a platinum capillary tube through a small hole in the closure and solder it

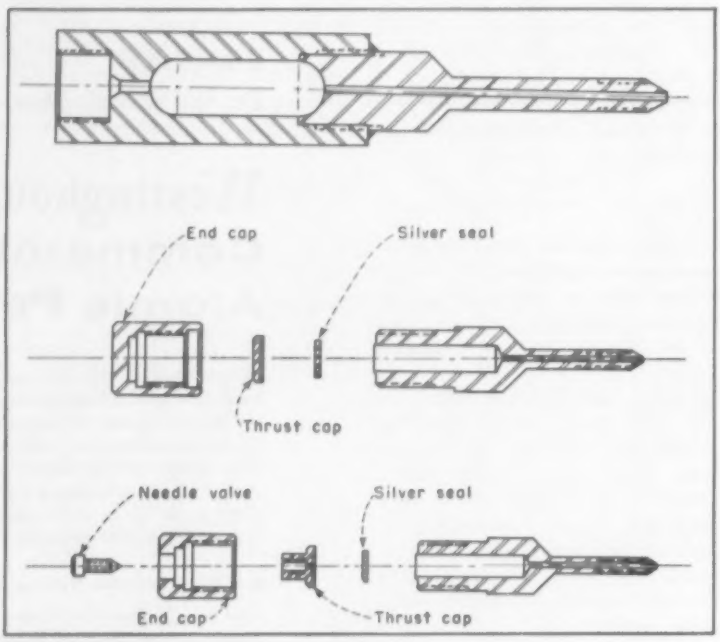

FIG. 3. Sampler designs—for solutions (top), for precipitating solutions (center), with pressure relief (bottom)

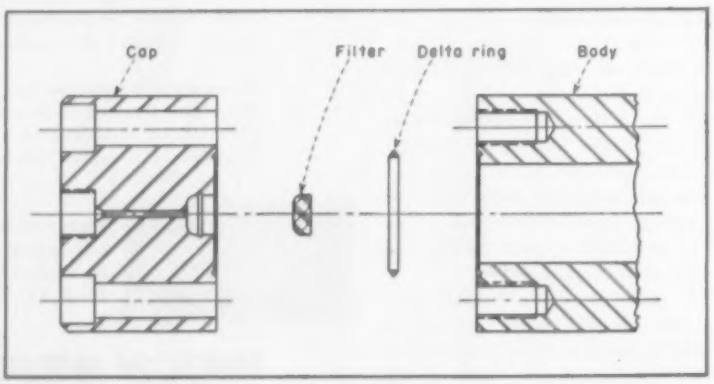

FIG. 4. Delta-sealed bomb

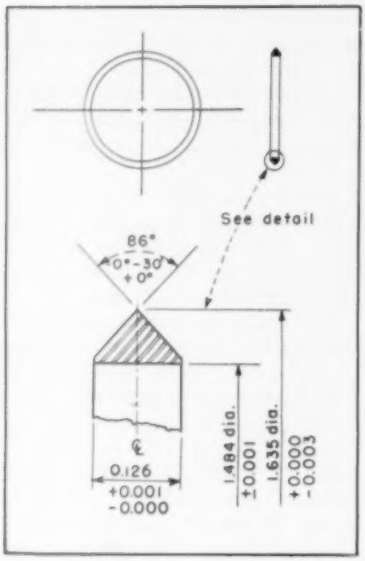

FIG. 5. Delta ring

with gold through a platinum bomb liner.

Operating procedure. The general operating procedure is as follows. One end of the bomb is closed. The tubing and valves are connected to both ends. The liquid and solid substances to be studied are put into the bomb. The bomb is then sealed and suspended in a 3-in. clamshell furnace, and the ends are packed with asbestos. The seals are tested with gas pressure, which is then released. The gaseous components, if any, are then introduced. Gas pressure is read throughout the run by a Heise gage.

The bomb is heated to temperature in an upright position to avoid driving solids and liquid into the gage line. When hot, the furnace with the bomb is tilted until approximately horizontal, then rocked through a 60-deg arc until equilibrium is presumed to have been established.

The furnace is then returned to the vertical. A sampling assembly, consisting of a sampler with closure, a valve, and a nipple (Figs. 1 and 2), is attached to the single valve terminating the line from the bottom of the bomb. Both valves are then opened until the sampler is filled, which usually takes less than a second. Both valves are then closed and the sampler assembly detached.

The sampler nipple is inserted into a test tube or other convenient containers, and the sample is collected. It is usually necessary to remove the plug or closure at the back of the

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sampler to blow or scrape the entire sample out. A variety of samplers has been designed (Fig. 3) for the various materials that may be collected. After removal from the sampler, the sample is analyzed by conventional methods.

After the sample has been taken, the bomb is agitated again, then resampled. If there is no change in liquid composition between successive samples, equilibrium is indicated.

If it seems likely that material in the delivery lines might cause significant error in the results, two samples may be taken; and the first, which served to rinse the lines, may be discarded. Account of this material must, of course, be kept if "wet-residue" determinations are to be made. If samples are taken before equilibrium is established, the composition of only the liquid phase can be measured. Subsequent runs must then be made to identify the solid phase, unless, as is frequently the case, the solid phase can be removed at the end of the run unaltered.

Gas-phase samples may be taken at the top of the bomb by a technique similar to that used for the liquid. The same types of sampling assemblies may be used and can then be attached to a gas-analysis apparatus. To minimize contamination it is wise to close off the gage line with a valve while sampling the gas.

Bomb seals. For handling corro-

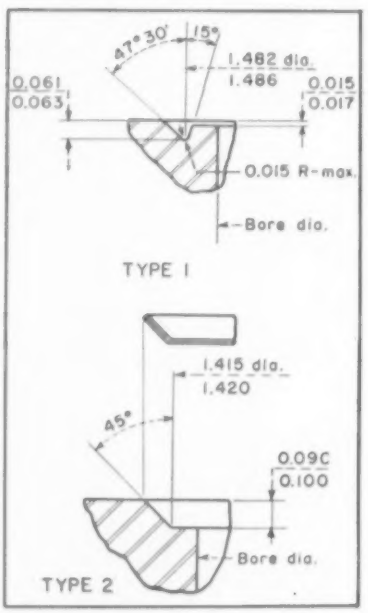

FIG. 6. Delta seal seats

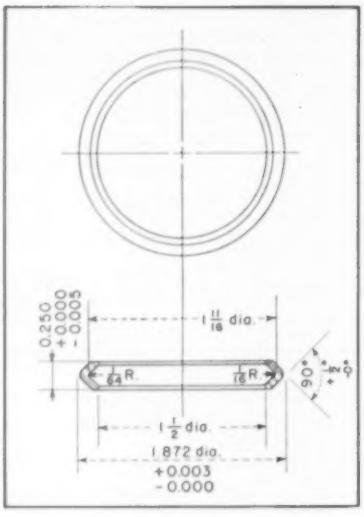

FIG. 7. Hollow delta ring

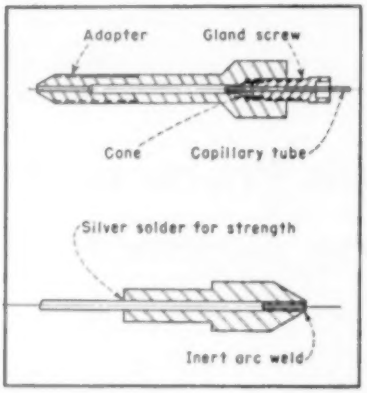

FIG. 8. Swage joint (top) and welded capillary joint for connecting hypodermic tubing to other components

sive solutions at pressures not greatly exceeding 10,000 psi, the delta-sealed bomb (*14*) (Figs. 2 and 4) was found more satisfactory than those using the Bridgman seal. Although the Bridgman seal (Fig. 1) has a higher ultimate range of useful pressures, its close clearances make it subject to freezing under mildly corrosive conditions. The many intricate shapes involved make it difficult to plate or clad with precious metal for corrosion protection.

The delta seal, on the other hand, is simple in construction and involves no close sliding fits or deformations. It is adaptable to complete protection of both seal and bomb by plating or cladding.

The delta-seal technique has apparently been used hitherto principally for large equipment, of the order of 3 ft in diameter. Existing formulas (*14*) for calculating delta-seal dimensions led to impossibly thin rings when scaled down for small experimental bombs. By changing the peripheral angle, it was found possible to make a delta ring of dimensions suitable for small bombs. Typical tested dimensions are shown in Figs. 5–7. The delta rings, as well as the bombs, can be made of any desired material, then plated or clad if necessary for corrosion resistance. Plating delta rings with a soft metal, such as copper or gold, also makes it unnecessary to put a high polish on both ring and seat. The dimensions of delta seals are fairly critical, and while they can probably be proportionally scaled up or down to a moderate extent, a little experimentation may be necessary for their application to a given use.

Type 2 delta-seal seat (Fig. 6) is used on bombs intended to be lined with protective metal, to avoid spinning the liner into a difficult reentrant angle. When used in a bomb without a liner, a Type 2 seat requires an additional thin conical gasket of soft metal on its tapered surface to make the initial seal with the delta rings.

In some cases, cutting of a platinum liner by a plated-steel delta ring has been avoided by placing rounded platinum gaskets above and below the delta ring. Welding of the precious metals to each other can be avoided by painting the surfaces with "Aquadag" and permitting it to dry before assembling the bomb.

Whatever closure is used, a bomb may be made with either one or both ends removable. The bombs described, of inner diameter about 1 in., were simpler to machine with closures at both ends. It is frequently possible to leave one end of a bomb assembled between runs.

For precision work it would be desirable to enclose the bombs in a heavy conducting sheath, preferably of aluminum or aluminum bronze (*11, 15*). Three or more inches of insulation at each end of a bomb is believed, however, to give a temperature distribution adequate for the type of study made with these bombs.

Hypodermic tubing is connected to other components by swage fittings or inert-arc welded joints (Fig. 8). Both techniques were worked out at Oak Ridge National Laboratory, but the present swage fittings are of Los Alamos design.

The filter-bomb sampling technique is not limited by atmospheric pressure. If vapor or inert-gas pressure is not

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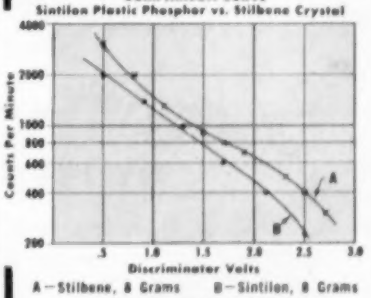
Sintilon Plastic Phosphor vs. Stilbene Crystal



A—Stilbene, 8 Grams B—Sintilon, 8 Grams
Radiation source, gamma rays from radium

SPECIFICATIONS
Sintilon Plastic Phosphor

Principal Emission Spectrum A.U.	4600
Relative Light Yield to Betas	.6
Decay Constant x 10^{-8} Second	.8
Density	1.05
Melting Point °C	110

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available to drive the solution through the filter, the sampler may be evacuated, either partially in advance or completely through a third valve at the back end of the sampler. Because of the small pressure difference available, a fine capillary line should not be used with this evacuation technique.

Conclusion

The filter-bomb sampling technique is versatile, simple, and safe. In the course of the development of fuel solutions for the Los Alamos Power Reactor Experiments, it has been used with highly corrosive acids and oxidants at temperatures from 100° C to 600° C. There is no reason to confine it to this temperature range or to aqueous systems. The present design of equipment is adequate for 20,000 psi. The method is adaptable to specialized modifications, for use with corrosive substances or for irradiation studies.

The general supervision and advice of Dr. R. Philip Hammond throughout this program is gratefully acknowledged. The skilled assistance of Clayton D. Ross and Summers H. Cox in the design and operation of the equipment is also acknowledged.

BIBLIOGRAPHY

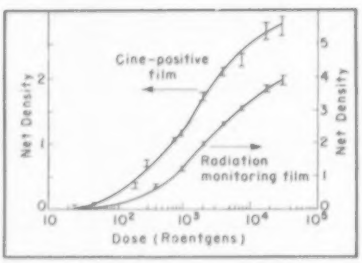
1. H. S. Booth, R. M. Bidwell, *Chem. Revs.* **44,** 477 (1949)
2. G. W. Morey, E. Ingerson, *Econ. Geol.* **32,** 607 (1937)
3. G. W. Morey, P. Niggli, *J. Am. Chem. Soc.* **35,** 1086 (1913)
4. W. F. Waldeck, G. Lynn, A. E. Hill, *J. Am. Chem. Soc.* **54,** 928 (1932); **56,** 43 (1934)
5. W. C. Schroeder, A. A. Berk, E. P. Partridge, A. Gabriel, *J. Am. Chem. Soc.* **57,** 1539 (1935); **59,** 1783 (1937); **59,** 1790 (1937)
6. W. L. Marshall, *Anal. Chem.* **27,** 1923 (1955)
7. W. A. Tilden, W. A. Shenstone, *Trans. Roy. Soc. (London)* **A178,** 23 (1885)
8. J. Königsberger, J. W. Müller, *Zentr. Mineral. Geol.* **A1906,** 339; **A1912,** 413
9. J. Königsberger, J. W. Müller, *Chem. Zentr.* **1906,** II, 268
10. G. W. Morey, J. S. Burlew, *Am. J. Sci.* **35A,** 193 (1938)
11. H. S. Booth, R. M. Bidwell, *J. Am. Chem. Soc.* **72,** 2567 (1950)
12. C. S. Hitchen, *Bull. Inst. Mining Met.* **1,** 364 (1935)
13. F. G. Straub, *Trans. Am. Soc. Mech. Engrs.* **1932,** F.S.P.-54-17, p. 221
14. A. R. Freeman, *Mech. Eng.* **74,** 969 (1952)
15. American Institute of Physics, "Temperature, Its Measurement and Control in Science and Industry," p. 617 (Reinhold Publishing Corp., New York, 1941)

Stabilization Film Processing for X- and γ-Ray Dosimetry

By STEVEN LEVINOS* and MARGARETE EHRLICH†

The technique of stabilization processing was developed by the Photographic Branch of the Signal Corps Engineering Laboratories for rapid processing of ordinary photographic material for military applications.‡ It was the purpose of the present study to investigate applications of this technique to X-ray and γ-ray dosimetry.

Stabilization processing, as modified for this investigation, employs a diaminophenol hydrochloride developer (later on referred to as Amidol developer) to which thiourea is added as a "bleach," so that essentially only the internal latent image is visualized. The developer is used in conjunction with a hardening bath and a thiourea solution (the "stabilizer"), which transforms the undeveloped silver salts into a transparent, comparatively insoluble compound, thus making the use of conventional fixing and washing of the films superfluous.§



CHARACTERISTIC CURVES of stabilization-processed films

The resulting image is not of archival quality, but its deterioration is slow enough for most practical purposes. It is very similar to the image obtained with other fine-grain developing agents used in conventional processing procedures. However, a test performed with one of the conventional fine-grain developers showed that the developing time required for equal results was at least three times that needed with stabilization processing. Even after

* Signal Corps Engineering Laboratories; present address: Ansco, Binghamton, N. Y.
† Radiation Physics Laboratory, National Bureau of Standards.

‡ S. Levinos, W. C. Burner, Photographic Engineering **2,** 148 (1951).

§ Some wash water is required when film holders are used, as these holders have to be thoroughly cleansed of all traces of thiourea before reuse.

that time, one thick emulsion was only incompletely developed and had a streaky appearance. Also, the developer was not as stable as the Amidol.

Film Staining

One drawback of the Amidol developer is that it stains the films. This necessitates a thorough removal of the developing solution from the film surface, best effected by "squeegeeing" the surface after development. Even then, staining after development cannot be entirely eliminated.

The photographic densities of processed film samples (exposed as well as unexposed) were determined four times over a time interval of about eight days. During this time, they were stored at about 26° C and a relative humidity not exceeding 60%. A density increase of about 0.10 was observed during the first two days. This increase was independent of density level. After this period, the density increase was negligible. The total density increment was the same for films stored in developing racks in which each film was separated from its neighbors and for films stored in bundles, in which one film was stacked tightly on the next one. The uncertainty introduced by density increase due to staining can be eliminated to a great extent by determining all film densities above the density of base, fog, and stain.

Useful Exposure Range

Data were obtained for fast X-ray film, radiation dosimeter film, and fine-grain ciné-positive film.

The fast X-ray film could not be developed to a density higher than 0.30, even after exposure to as much as 10,000 r of Co^{60} gamma radiation. The characteristic curves for the other two film types are shown in the graph. The ordinate represents density above base, fog, and stain; its spread is that of five individual densitometric readings each, repeated four times over a period of eight days, on two identically exposed film samples.

When processed in a conventional manner in X-ray developer, the useful ranges of these two film types are approximately 5–150 r and 20–600 r, respectively. When stabilization processing is used, the useful range of both types is seen to extend roughly from 100 r to 30,000 r. The range shift and range extension seem to be effected without prohibitive loss in contrast.

Developer Aging

The processing action of one batch of solutions was followed up over a period of one week, during which the solutions were kept at a temperature of 68° F. The weakening of the solutions over this period produced a reduction in the density of identically exposed films, corresponding to less than a 5% change in exposure.

It was noted that a brownish precipitate formed in the developing solution some time after the first batch of film was processed. The amount of precipitate increased with further developings. However, the presence of the precipitate had no apparent influence on the quality of the developed films.

Processing Time

A variation of developing time by ±1 min produced a change in the density of the radiation dosimeter film that was equivalent to about a ±25% variation in exposure. There was no change in density when the stabilizing time was varied from 1 to 3 min.

Fading Characteristics

As stabilization processing develops mainly the deep-seated latent image, it was thought that the effect of latent-image fading (which occurs to a considerable extent on the grain surface,

Chemicals Employed

Developer

Water (68° F)	3 liters
Ammonium sulfite, $(NH_4)_2SO_3.H_2O$	300.0 gm
Diaminophenol hydrochloride (Amidol)	27.2 gm
Ammonium bromide	8.0 gm
Thiourea*	1.6 gm
Water to make	4 liters

Stop Hardener

Water (68° F)	3 liters
Chromium ammonium sulfate	120.0 gm
Water to make	4 liters

Stabilizer

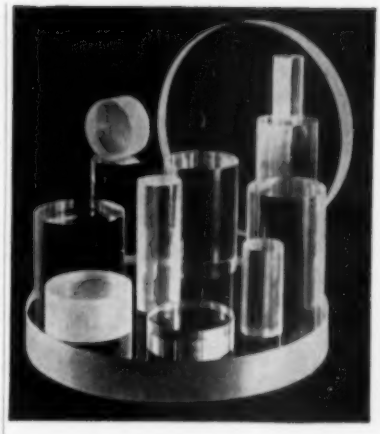
Water	3 liters
Thiourea	120.0 gm
Glycerine	20.0 cm³
Water to make	4 liters

Processing Times at 68° F

Development	3 min
Hardening	1 min
Stabilization	2 min

NOTE: Processed film should not be washed

*Added as solution: dissolve 16 gm thiourea in 250 cm³ water and use 25 cm³.



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upon exposure to oxygen and water vapor) might be diminished. Also, it was thought that this deep-seated image might exhibit a different energy dependence. Such effects were not observed in the present tests.

Conclusions

Stabilization processing is a promising procedure for fast field development of photographic dosimeter films where water supplies are scarce. Used in conjunction with conventional processing in X-ray developer, it could facilitate coverage of the X- and gamma-ray range of interest in field work with a much smaller number of film types than is needed when films are processed solely in X-ray developer.

* * *

Most of the experimental work for this study was carried out by Jae R. Brooks, of the National Bureau of Standards, and Willard C. Burner, of the Signal Corps Engineering Laboratories. The portion of the work that was carried out at the National Bureau of Standards was supported by the U. S. Army Signal Corps.

Americium Electrodeposition

By ROY KO
Hanford Atomic Products Operation
General Electric Company
Richland, Washington

Electrodeposition is one of the best means of preparing thin, uniformly distributed films of radioelements. Little work, however, has been done on electrodepositing americium—useful for standardizing alpha counters and for alpha-energy analyzers.

Britain (*1*) made an unsuccessful attempt to electrodeposit americium from a sodium bicarbonate-carbonic acid solution. He also tried Haissinsky's (*2*) acetone-alcohol method developed for actinium deposition, but obtained nonadherent deposits that varied in yield from 25 to 90%. A successful electrodeposition from a sodium chloride solution at 90° C has been reported (*3*), but a maximum of 40% deposition was obtained here under the conditions prescribed.

The author investigated the precipitation of metal hydroxides at the cathode by the electrolytic formation of base. This method should be applicable to the deposition of any element having a slightly soluble hydroxide and provides a means for preparing thin, adherent films of the more electropositive elements that cannot be deposited as metals from aqueous solutions. In particular, this method is convenient for preparing thin films of the rare earth and actinide elements. This article reports its application to americium.

Procedure for Electrodepositing Americium

- Assemble electrolysis cell using 22-mm-diameter stainless steel, platinum, or copper disk cathode.
- Add 4 ml of solution of 0.20*M* HCOOH, 0.15*M* $HCOONH_4$.
- Add americium solution not exceeding 400 microliters.
- Place platinum anode stirrer 10 mm above cathode and rotate at approximately 200 rpm.
- Electrolyze at 80–100 ma for 1–2 hr (see table).
- At end of electrolysis, siphon out solution with current on. Rinse with dilute NH_4OH and then with acetone.
- Disassemble cell and ignite disk to redness over bunsen flame.

Experimental

The equipment and apparatus have been described elsewhere (*4*). All experiments were made at room temperature using americium-241. Deposition yields were calculated from measurements of americium alphas on the electrodeposited disk.

Americium was electrodeposited from a formic acid-ammonium formate solution on stainless steel, platinum, and copper using a cathodic current density between 50 and 65 ma/cm². Quantitative deposition was obtained in a solution 0.20*M* in formic acid and 0.15*M* in ammonium formate. Electrodeposits of americium from 0.01 microgram or 7.4×10^4 dpm (disintegrations per minute) to 5.32 micrograms or 3.6×10^7 dpm have been made on stainless-steel cathodes 1.54 cm² in area in 1–2 hours (see table).

Discussion

Metal hydroxides can be precipitated at the cathode from an initially acid solution by the reduction of hydrogen ion or water and the consequent increase in the hydroxide ion concentration at that electrode. The precipitation of the metal ion can be made quantitative if the anode reaction produces no hydrogen ions and permits the entire solution to become basic. In the absence of readily oxidizable substances, the anode reaction in aqueous solution produces one hydrogen ion equivalent per Faraday by the oxidation of water

$$2H_2O = 4H^+ + O_2 + 4e^- \quad (1)$$

The same number is lost at the cathode by hydrogen ion reduction so that no net change in *p*H of the solution occurs. Formate ion, however, is readily oxidized at the anode with the formation of only half an equivalent of hydrogen ion per Faraday

$$HCOO^- = CO_2 + H^+ + 2e^-, \quad E^0 = 0.196 \text{ volts} \quad (2)$$

Equation 2 represents the complete anode process at low current densities (*5*). The net electrolytic process, then, in the presence of formate ion is the loss of half an equivalent of hydrogen ion per Faraday. There is a net decrease in the hydrogen ion concentration of the solution as electrolysis proceeds and the quantitative precipitation of americium at the cathode becomes possible.

BIBLIOGRAPHY

1. J. W. Britain. Advances in the techniques for the preparation of thin films of radioactive materials, CC-3895 (1946)
2. S. Cotelle, M. Haissinsky, *Compt. Rend.* **206**, 1644 (1938)
3. L. G. Cook, Chalk River Project Progress Report, PR-CE-18, April–June, 1953
4. H. W. Miller, R. J. Brouns, *Anal. Chem.* **24**, 536 (1952)
5. A. N. Kappana, B. R. Deorus, *J. Indian Chem. Soc.* **28**, 287 (1951)

Electrodeposition of Various Amounts of Americium*

Micrograms Am added to cell	*Percent deposition*	
	In one hour	*In two hours*
0.01	100	
0.09	98.6	
0.38		96
0.89		97
1.77		99.7
3.54		97.6
5.32		97.6

* Deposition conditions: 0.20*M* HCOOH, 0.15*M* $HCOONH_4$, 80–100 ma, 1.54-cm² stainless steel cathode.

Calculating Average Counting Rates

By D. B. ZILVERSMIT,* and ALAN L. ORVIS†

To determine the counting rate of a radioactive sample it is the practice in most laboratories to count two or more replicate samples, each for the same length of time or for the same number of predetermined counts. The choice of procedure is frequently one of convenience or may depend on the available equipment.

It is not always realized that the procedure of obtaining the mean counting rate from the individual determinations is fundamentally different for the two procedures. In the instance in which one counts two or more samples for the same length of time, the proper manner of determining the mean counting rate is the calculation of the arithmetic mean of the individual rates. However, in the case of predetermined counts, one should calculate the harmonic mean of the individual counting rates or, which amounts to the same thing, determine the arithmetic mean of the individual counting times before dividing the average time into the predetermined counts. The following algebraic expressions illustrate the differences in the two procedures.

Counting for Preset Time

Let X_1, X_2, X_3 . . . X_n represent the total number of counts in each of n counts for a time t. The appropriate average counting rate would be that rate which, if it should prevail for the total counting time nt, would give the same number of total counts $\sum_1^n X_i$. Obviously this rate would be $\sum_1^n X_i \Big/ nt$ which equals $\left(\sum_1^n X_i/t\right) \Big/ n$, which, in words, is the arithmetic mean of the individual counting rates.

Predetermined Counts

Let X be the preset count and t_1, t_2, t_3 . . . t_n be the individual times required to count X counts. Again the appropriate average counting rate would be the one which, if it should prevail during the entire counting time $\sum_1^n t_i$, would give the same number of total counts nX. This average rate would thus be $nX \Big/ \sum_1^n t_i$. This expression can be transformed into $X \Big/ \sum_1^n t_i/n$ (1) or into $n \Big/ \sum_1^n t_i/X$ (2). Expression (1) reads in words: the preset count divided by the arithmetic mean of the individual counting times; the equivalent expression (2) represents the harmonic mean‡ of the individual counting rates. The inequality of the two expressions

$$nX \Big/ \sum_1^n t_i \text{ and } \sum_1^n X/t_i \Big/ n$$

may easily be seen by inspection. However, a numerical example might illustrate the difference between the arithmetic and harmonic means of the individual counting rates in the case of predetermined counts. Suppose that one sample is counted twice for a total of 1,000 counts, and that the counting times are 9 and 11 sec, respectively. The correct average counting rate would be obtained from expression (1) $1{,}000/(9 + 11)/2 = 100$ cps. However, if we had calculated the average counting rate as the arithmetic mean of the two individual rates as $(1{,}000/9 + 1{,}000/11)/2$, we should have obtained the erroneous answer of 101 cps.

The difference between the two methods of calculation will be greater when the counting times differ more than in this example. It would therefore appear advisable to use the method of averaging counting data that gives correct results irrespective of the magnitude of the difference between replicates.

* Department of Physiology, University of Tennessee, Memphis, Tenn.
† Section of Biophysics and Biophysical Research, Mayo Clinic, Rochester, Minn.
‡ A harmonic mean is defined as the reciprocal of the arithmetic mean of the reciprocals of the values to be averaged.

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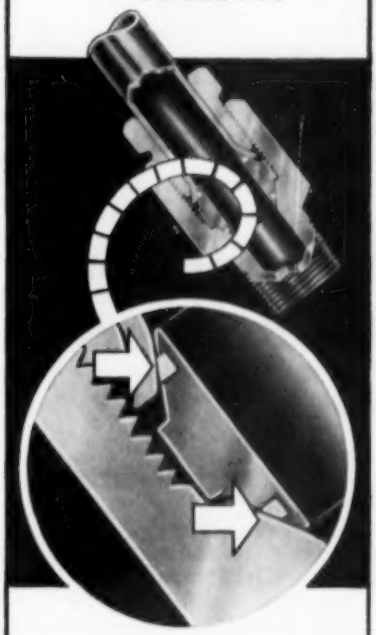

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Enrichment (% U^{235})	*Captures in U^{238} per fission*	*Net neutrons available for leakage and irradiation*
0.7 (Nat'l. U)	1.04	1.12 − 1.04 = 0.08
2	0.95	1.12 − 0.95 = 0.17
20	0.10	1.12 − 0.10 = 1.02
90	0.0006	1.12 − 0.0006 = 1.12

Fuel Enrichments for Reactors for Power or Research

The advantages of using slightly enriched uranium in power reactors and highly enriched fuels for research reactors were pointed out to a management group recently by James A. Lane of Oak Ridge National Laboratory.

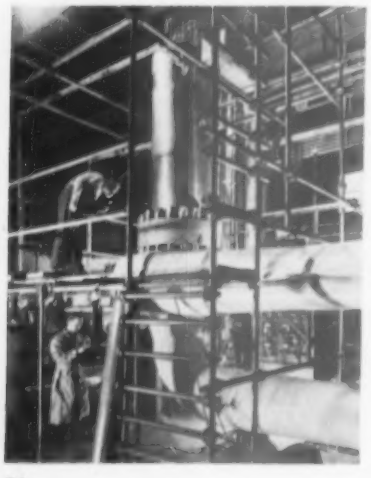
As shown in the table, fewer neutrons are nonproductively lost in U^{238} when less U^{238} is present. Thus, the higher the enrichment, the more neutrons are available for losses due to leakage and absorption by materials and structure. Per U^{235} fission, 2.12 neutrons are made available; if one neutron is used to sustain the chain reaction, 1.12 neutrons are available for all losses.

Design flexibility of a power reactor can be improved by increasing the U^{235} concentration from 0.7% to 2%—this doubles the number of neutrons available for leakage and absorption by coolant, cladding, and moderator without greatly decreasing the conversion ratio (i.e., captures in U^{238} per fission divided by 1.18).

There are almost as many net neutrons available for leakage and other losses when using 20% U^{235} as when using 90% U^{235}. Thus the core size and critical masses of 20% and 90% cores are about the same. (For swimming-pool-type cores, they are the same due to the moderating effect of the U^{238} present in the 20% case.)

The most important criterion for research reactor performance is not total number of neutrons available for irradiation, but achievable neutron flux. The smaller critical masses of the highly enriched cores (20–90%), due to lower U^{238} absorptions, permit higher fluxes for a given power level and thus improve performance.

Cover—Testing Pressurized-Water Pumps for PWR



Prototype canned-rotor pumps for the 60-Mw PWR (Pressurized Water Reactor) plant have been tested in closed loops with water at 500° F and 2,500 psi system pressure.

For each of the three prototypes, tests included: 500 pressure-cycle tests in which hydrostatic pressure was varied from 500 to 2,500 psi continuously, start and stop tests, and long-time runs. Every 15 minutes, a staff of nine test engineers (on each shift) took several hundred readings of temperature, pressure, current, voltage, velocity, pumping rate, and other variables throughout the motor, pump, and test loop.

Unit shown under test at Allis-Chalmers in Milwaukee is rated at 1,250 hp, 16,700 gpm, 3,600 rpm, and 307 ft head. Rated for full- and half-speed operation, it has stainless steel cans hermetically sealing both stator and rotor from water in the "air" gap. Silco-Flex silicone rubber insulates the water-cooled motor, which has fluid piston bearings that use water to position rotor and impeller during operation—thus, minor surface scratches do not affect operation.

Two similar, but slightly larger (18,300 gpm, 321 ft head), units will pump pressurized, hot, and radioactive water from the reactor to two heat exchangers. The other two loops will use Westinghouse pumps (see p. 88).

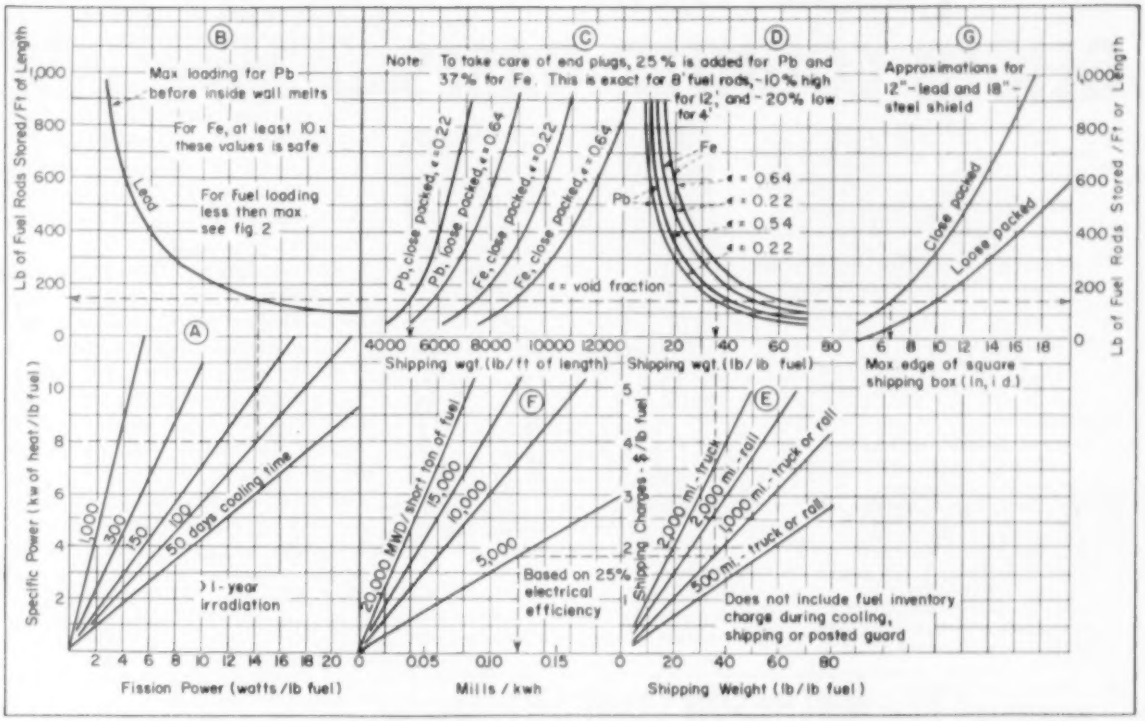


FIG. 1. Shipping weights for maximum-load spent-fuel shipments. Conditions: fuel length = 4–12 ft; ambient temperature = 100° F; packed in air; no internal cooling; inside lead is at 500° F; outside surface activity of container = 50 mr/hr. Close packed—cylindrical rods stacked with tangential contact on all sides. Loose packed—spacing as in typical reactor fuel-element assembly

Economics of Shipping Spent Nuclear Fuel Elements

By CHARLES E. DRYDEN*
Atomic Power Equipment Department
General Electric Company
Schenectady, New York

Removal of spent fuel from a nuclear power reactor poses a problem of how to recover the greatest economic value from the irradiated fuel elements.

Present AEC regulations on the handling of fissionable fuel anticipate that residual U^{235} and Pu will be returned to Government inventory by the user in a decontaminated form. Since it is unlikely that each individual nuclear power reactor station will have reprocessing facilities on location, the fuel elements will be packed in γ-shielded containers and shipped to a reprocessing plant.

Another alternative is to ship the spent fuel to a facility that employs the irradiated fuel for its gamma-ray value. After an economic period of use at this plant, the fuel may then be shipped to a chemical processing plant for recovery of the fissionable fuel value.

Design Basis

The design of shipping containers for the above applications requires an economic study involving cooling time, shielding materials, and heat transfer to minimize the shield-fuel weight ratio and thus to save shipping costs. The results of such design studies are shown in Figs. 1 and 2. It should be recognized that the design for shipping spent fuel rods is based on a large-scale shipping program with its accompanying cost savings and, hence, does not purport to apply to present day practices for shipping various configurations of reactor fuels. There follows a summary of the methods and data as well as a typical example of how to use the graphs.

Energy release. The ratio of decay power to reactor operating power as a function of cooling time was based on infinite irradiation time for the fuel elements. The data are plotted in Fig. 1A. This admittedly gives too high an energy level for short irradiation times, but for exposures longer than one year, the values are within the engineering accuracy of the design method. It was further assumed that beta energy equals gamma energy equals one-half of total energy.

Shielding requirements. For long cylindrical or square containers, the lowest shield-weight ratio is obtained by (a) use of the highest density material and (b) packing the greatest amount of fuel rods inside of one container.

Lead and steel are the only shielding materials that qualify from the standpoint of high density and low material and fabrication costs. Average

* On leave from Ohio State University, Columbus, Ohio.

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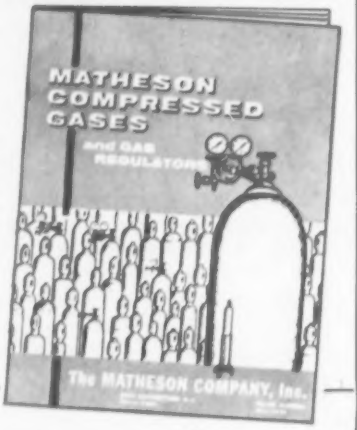

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gamma-ray absorption coefficients are 16.1 ft^{-1} for lead and 10.6 ft^{-1} for steel.

The calculations allow for self-absorption within the fuel-rod bundle and the approximation that the build-up factor is compensated for by increase in surface area on moving from the center to the outside of the shield. The activity at the outside surface was to be 50 mr/hr so that radiation at the side of the car would not exceed 10 mr/hr.*

Heat dissipation. The design uses natural-convection air cooling since this is the simplest and most fool-proof.

The major resistance to heat transfer is in the outside air film. The driving temperature difference is fixed by the melting point of the inner container wall in the case of lead. Since the outside container surface per unit of storage volume decreases as the latter increases, this limits the quantity of heat-generating fuel that can be stored within a shielded container (See Fig. 1B). For steel, the limitation may not necessarily be its melting point but a safe temperature for the fuel element itself, particularly if aluminum-clad elements are handled.

Criticality. Since there is no moderator present, no critical diameter limitation for natural or slightly enriched fuels exists. For any fuel enrichments above the slightly enriched case, and especially for fully enriched fuels, critically safe geometry must be maintained. Each particular type of enriched fuel loading will require an exponential test to establish limits of safety.

Transportation. Rail and motor freight were considered in this study.

Interstate Commerce Commission Regulation (Article 73-391) requires that the Bureau of Explosives, Association of American Railroads, must approve all rail freight shipments over 2.0 curies for the radium series. In the case of solid cesium-137, cobalt-60, and iridium-192, 300 curies can be shipped without approval if packed in Specification ICC-55 containers. For all other radioactive materials, up to 2.0 curies may be shipped without approval. Since it is anticipated that a spent-fuel shipment will have a loading in excess of 20,000 curies, approval is automatically required.

Rail express was 3–4 times as expensive and thus was not included in the

* Article 73.393(g) in Code of Federal Regulations for 1955 Usage, Interstate Commerce Commission.

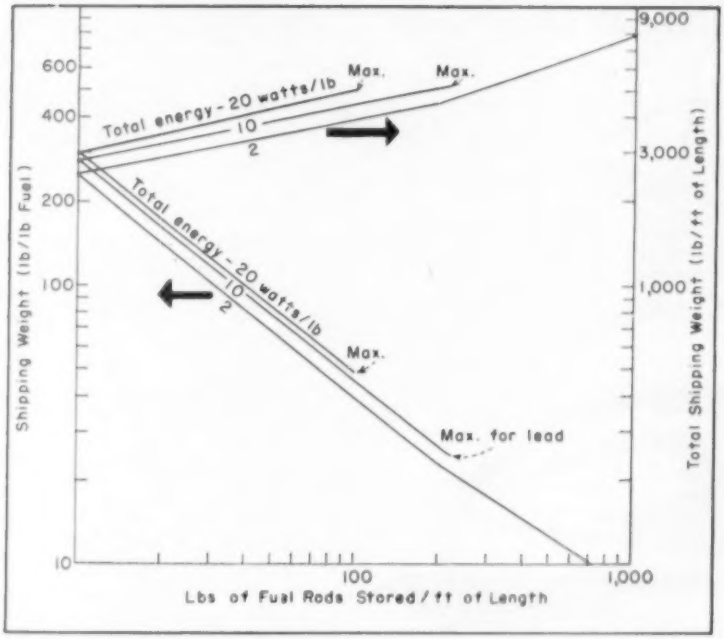

FIG. 2. Shipping weights for less than maximum loading. Data is given for lead and close-packed fuel rods. For loose-packed rods, add 10%. For iron, multiply the weight by 1.53. Dashed line is sample calculation for maximum fuel loading (see text)

future commercial picture. Class 45 (heavy machinery) shipping rates were used.* For distances of 300–1,000 miles, rail and motor freight are competitive. Beyond 1,000 miles, truck rates are higher than rail.

If ocean freighter shipping is involved, the following costs ($/ton-mile) can be used for shipping to U. S. ports: Central America, Venezuela, Columbia—0.0186; Brazil, Argentina, Chile—0.0105; Europe—0.0085; and Far East—0.0048.

Travel speeds in miles per day were conservatively chosen as follows: railroad—400, truck—400, barge—100, and freighter—300.

Shipping cost estimates. The costs shown in Fig. 1E are based on the rail and motor freight shipping rates discussed earlier and fixed charges on the shipping container. The latter are 20% per annum on a capitalization charge of $1 per pound of container and a 50% use time for the container. The cost includes round-trip shipping of the container.

No allowance was made for fuel-inventory charges during cooling and shipping nor for the cost of a posted guard as required by the AEC regulations. For a rough estimate of such items, add 50% to the costs given in Fig. 1E at an optimum cooling time of 100 days.

Minimum shipping weight and hence minimum cost results from maximum loading of fuel in one container. Figure 1 was made up on this basis. For loading less than the maximum, use Fig. 2.

Example of Maximum Fuel Loading

As an example, the equivalent power cost in mills/kwh for shipping spent fuel elements of the following specifications is desired

Operating specific power = 8 kw of heat/lb
Exposure = 5,000 Megawatt days per ton of fuel
Length of fuel element = 8 ft
Cooling time = 100 days
Shipping distance = 1,000 miles
Type of shielding = lead
Type of packing = close packed

Starting with Fig. 1A, follow the horizontal line from 8 kw/lb to the 100-day cooling line, vertically to Fig. 1B curve, then horizontally to the left and read the fuel loading as 140 lb per ft of length. Following

* Personal communication. New York Central Railroad Traffic Office.

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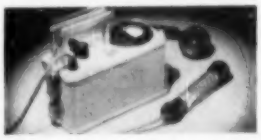

Portable laboratory or field survey meter (.5; 5; 50 mr/hr full scale) is built to FCDA specifications—the only CDV-700 type survey meter which can be exposed continuously to high intensity radiation without detector failure. Probe uses Anton halogen quenched, very thin wall, stainless steel counter tube. Accuracy assured from -55°C to +75°C.

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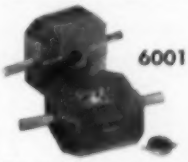

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the same horizontal line to the right, the total shipping weight is read from Fig. 1C as 4,900 lb/ft for close packing or $4{,}900 \times 8$ ft = 39,200 lb total weight. This container is well over the 25,000–30,000 lb maximum allowable for trucks unless special routing privileges are granted in the states through which the load is carried.

The shipping charges are next obtained by moving horizontally on the same line to Fig. 1D, which gives 36 lb/lb as the shipping-to-fuel weight ratio. Move vertically down at this point to Fig. 1E and 1,000 miles shipping distance, then move horizontally at this point and read \$1.85/lb of fuel as the shipping charge. For equivalent costs in mills/kwh, continue the horizontal line to Fig. 1F and 5,000 Mwd/t line, then vertically to the abscissa scale and read 0.121 mills/kwh for a thermal efficiency of 25%. Costs at other efficiencies can be computed by noting that cost is inversely proportional to efficiency.

To find the size of the shipping container, use Fig. 1G at 140 lb/ft loading and obtain 6.5 in., i.d. The approximate wall thickness is 12 in. To find the exact wall thickness, X, use the following formula

$$X = 0.565\left(\sqrt{\frac{W}{\phi\rho} + S^2} - S\right)$$

For the example illustrated, W = shipping weight = 4,900 lb/ft of length, ρ = 711 lb/ft^3 for lead, s = i.d. in ft = 6.5/12 = 0.54 ft, ϕ = 1.25 for lead. Substituting in the formula gives X = 1.056 ft or 12.7 in.

Comparison of Lead and Iron

The comparison between lead and iron can be illustrated with Fig. 1D. Shipping weights for steel or cast-iron containers of less than 36 lb/lb of fuel (as required in the example using lead) are possible if a loading greater than 240 lb/lb of fuel is used. This threshold value is only 1.7 times greater than that for fuel loading in the lead container, and hence safe from the temperature distribution standpoint. From Fig. 1C at this loading, the total shipping weight will be 8,300 lb/ft or 66,400 lb/container for 8 ft fuel rods.

* * *

The advice and encouragement of J. M. Frame, H. W. Huntley, and R. G. Lorraine, Atomic Power Equipment Department of the General Electric Co., is gratefully acknowledged. The data on water shipping was kindly supplied by John J. Zeiss of the Traffic Dept., General Electric Co.

TECHNICAL ADVANCES

Sidelights at the ANS Meeting The following items, culled from the recent Chicago American Nuclear Society meeting, reflect the great wealth of useful material presented in all of its sessions. Major events at the meeting are reported elsewhere in this and subsequent issues of NUCLEONICS.

Neutron scattering cross sections. A. Langsdorf and R. O. Lane reported on extensive measurements of differential neutron scattering cross sections. (Their detector is energy-insensitive and therefore elastic and inelastic events are indistinguishable.) The data will help fill a long-felt need for more complete data on the behavior of fast neutrons. The detailed angular distributions are particularly important in the case of shields; most core calculations can be done quite adequately with transport cross sections, which can be obtained very simply from these detailed angular distributions. Inelastic scattering data must come from other experiments.

Thirty-nine elements were measured at 20 energies from about 50 kev to 1.5 Mev using neutrons from the Li (p,n) reaction. Measurements were made simultaneously at five angles: 22, 54, 92, 112, and 144 deg, with 5-deg resolution. Still more data are to be taken, but the patterns of behavior with atomic number are sufficiently well established to lend confidence to extrapolations to unmeasured elements. Tabulations of the data are available from A. Langsdorf at Argonne National Laboratory and soon will be issued in report form.

Capture gamma rays. Our knowledge of the spectra of capture gamma rays will grow more acute as results come out of a 7.7-meter bent-crystal gamma-ray spectrometer of the DuMond type described by Argonne's B. Hamermesh and D. Rose. By measuring at very small angles (<30 min) it is possible to measure the wavelengths of gamma-rays by the same Bragg-angle technique that is used for lower X-rays. The new rig will complement pair and scintillation spectrometers currently used to study capture spectra in that it operates best in the region below 2 Mev and accuracy improves with decreasing energy.

The very small angles involved necessitate very exact construction and measurements. The source is a sample close to the core of the CP-5 reactor viewed via a straight-through beam hole. The diffracted beam is separated off by a focusing baffle consisting of 108 lead plates $11 \times 40 \times 0.040$ in. Detection is by a bank of NaI crystals and photomultipliers.

One particularly nice touch eliminates the need to measure angles directly: One of the plates of an optical interferometer is coupled to the spectrometer table so as to follow its motion. Since a relation formally similar to the Bragg equation governs the production of interference rings, one can relate gamma-ray energy directly to the wavelength of the optical radiation using only the known crystal plane spacing and the radial distance at which the interferometer mirror is being pushed and interference-fringe number.

Neutron photography. K. H. Sun talked about the application of his neutron scintillators (described on p. 46) to photographic detection of neutrons. He simply lays one of the scintillating sheets on a fast photographic emulsion (Kodak TriX). The resulting system permits one to distinguish the rings in the characteristic pattern of neutrons diffracted by a crystalline powder. It also could make a film badge dosimeter for neutrons, for a dose of 3×10^4 thermal neutrons gives a "just-visible" image. Since the permissible daily dose is 5×10^2 thermal neutrons/cm² this threshold is well below permissible.

Enriched targets improve cyclotron yields. Farno Green and John Martin of Oak Ridge National Laboratory described the use of target isotopically enriched in Cr^{54}, Te^{125}, and Te^{130} to produce carrier-free Mn^{54}, I^{125}, and Te^{130}, respectively, by (p,n) reactions in the 86-in. cyclotron. Key to the new method is the fact that electromagnetic separation methods have been improved sufficiently to permit economical isolation of even low-abundance isotopes. Among the merits are the fact that the target material can be recovered since product differs chemically . . . this would not be true in reactor neutron-capture irradiations. Other isotopes such as Na^{22}, Al^{26}, and Ca^{47} should also become cheaper by this method.

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APPLIED RADIATION

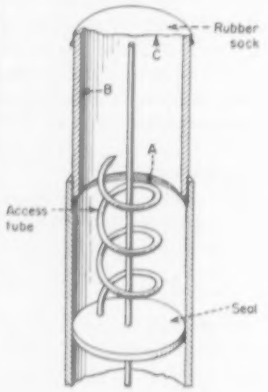
Bell Labs Tests Leaks with Cs^{134}

How do you find a leak that might cost a quarter of a million dollars? This is what it might cost to pull up and repair one of the repeater amplifiers of the first transatlantic voice cable. A leak that causes failure of a single circuit element in a repeater is enough to interrupt operation until a repair is made.

At the Bell Telephone Laboratories in Murray Hill, N. J., A. H. Lince, James Struthers, and C. C. Houtz have solved the leaktest problem by combining helium and radioisotope methods.

A repeater consists of 17 cylindrical units in plastic tubes, coupled end to end. They are housed in a metal cylinder 8 ft long and $1\frac{3}{4}$ in. in dia. Three pairs of seals protect it—one for moisture, one for pressure, and one as an outer barrier. The system is designed to operate for 20 years or more without interruption under water pressures as high as 6,000 psi. A dessicant can take care of 3 gm of water in the 20 years, but a leak that admits more is intolerable.

Five conventional helium tests examine the six seals, but each helium test requires an access tube. After the test the access tube must be sealed off and coiled out of the way. How can you test the tube for leaks after it is sealed? Earlier repeaters now in use between Havana and Key West were submerged for a week at high pressure and then weighed. But corrosion and similar chemical effects might cause weight changes greater than that due to a tolerance leak, 1 mg of water.



Today's better way is a tracer method. As shown in the sketch the sealed access tube A is submerged in a solution of $Cs^{134}Cl$, which is contained by a tube B screwed into the end of the repeater housing for the test. Over the end goes a watertight sock made of rubber, and the whole system is submerged in a water bath at 9,000 psi for 60 hr. The sock confines the radioactive solution to the useful volume so that the total activity required is not hard to shield.

After the soaking period the radioactive solution is drained off, and a special washing procedure removes any that may cling to the surfaces that have been exposed to it. A survey of the access tube will detect a leak that has admitted as little as 1 mg of liquid. The leak can be found, for the radioactive salt is deposited at the site by evaporation of the water inside the tube. Counts are customarily made with the counter tube inserted at four different points between the access tube and the repeater wall. If a high count is recorded at one of them, a more careful search usually finds the leak.

Why Cs^{134}? It is cheap ($1/mc), has a hard gamma (2 Mev), is available at high specific activity (1 mc/ml is used), and has a half-life long enough to obviate decay problems and short enough to make disposal fairly simple (2.3 yr). The hard gamma penetrates the tube wall if it leaks, and a special narrow Anton G-M tube permits localized counting.

After a test most of the solution is recovered to be used again. An alcohol-water washing procedure removes contamination from the volume that held the radioactivity. After the wash the background count is less than 1.5 times normal. The wash solution is repeatedly admitted and then removed by evacuation. Boiling of the alcohol agitates and removes radioactive matter from threads and corners. Disposal of radioactive cesium from the wash water requires an ion-exchange tube in which the cesium replaces hydrogen.

A tape recording simplifies the routine of repeated washings. Engineers at Bell's Hillside Laboratories, where the tests are run routinely, have recorded operating directions so that technicians can dispense with stop watches and printed instructions: "When you get the word, open stopcock A . . . . Do it . . . NOW."

BOOKS

Physics of Fully Ionized Gases

By LYMAN SPITZER, Jr. (Interscience Publishers, Inc., New York, 1956, ix + 105 pages, paperbound—$1.75, clothbound—$3.50).

Reviewed by W. P. ALLIS, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass.

This is an excellent pocket book of 100 pages containing both clear accounts of the phenomena and a wealth of useful formulae. The reader should be warned, however, that the plasmas discussed are astronomical in character and not often found in the laboratory. Langmuir defined a "plasma" as a gaseous state of matter that protected itself from its environment by space-charge sheaths. For this to be, all dimensions of the plasma had to be greater than a Debye length.

Spitzer's plasmas must be much greater yet. The basic relation controlling Langmuir's plasmas was always the "plasma balance equation," which equated the rate of ionization to the rate of flow of ions to the walls through the sheaths. The latter acted as filters to equate electron and ion flows. It is the condition of plasma balance that limits the electric field that may be applied to a plasma and produces the flat, or even negative, characteristic of a laboratory discharge. Spitzer's plasmas are assumed to have no walls, no wall currents, and therefore no rate of ionization. The gas is as fully ionized as it is going to be, and this is the meaning of "fully ionized," not necessarily that all electrons, or even one, have been removed from every atom.

The resistivity of a plasma, due to collisions of electrons with neutral molecules, is known to decrease with current density so that the product of the two is nearly constant. However when the degree of ionization exceeds 1 or 2%, the resistivity due to collisions with ions exceeds that due to collisions with molecules, and this resistivity does not vary much with the current density. The plasma has then become "ohmic." Spitzer deals with ohmic plasmas.

Chapter 1 deals with the orbits of charged particles in nonuniform magnetic fields by considering the motion as primarily circular and studying the motion of the "guiding center," both across and along magnetic lines of force. In particular he considers the trapping of charged particles between "magnetic mirrors" and their acceleration when two magnetic mirrors approach, the mechanism proposed by Fermi to explain cosmic ray energies. One would have welcomed an additional chapter in which the effects of collisions were included in first order.

Chapter 2 sets down the hydrodynamic equations for a plasma with the assumption that the pressure is a scalar. An additional section on nonscalar pressures would have been welcome here. The paradoxical relation between the macroscopic motion of charged particles and the motion of their guiding centers is discussed. Either one can vanish when the other is finite.

Chapter 3 discusses some problems, in particular the drift of charged particles across a magnetic field. The classical formula, varying as $1/B^2$, is derived, and Bohm's formula, varying as $1/B$, is written with the notation that no theoretical derivation is available. One is led to wonder how much further our knowledge might be if Bohm's peculiar genius in this field had remained available. The assumptions made in discussing the pinch effect do not correspond to the situation realizable in the laboratory.

Chapter 4 contains a very nice, though short, discussion of the propagation of electromagnetic, of hydromagnetic (Alfven), and of electrostatic (plasma) waves through a plasma.

Chapter 5 is mainly a discussion of the conductivity of a "completely ionized" plasma. The principles used and approximations made are clearly presented but the derivation is absent. It has to be in a book of this size, although it can be greatly shortened from that given by Chandrasekhar if use is made of the potentials recently introduced by M. Rosenbluth. The theoretical conductivity has recently been verified by both Kantrowitz at high pressures and temperatures and by L. Goldstein at low pressures and temperatures although the experiments still allow an appreciable factor of uncertainty. This chapter also gives formulae for relaxation times, for thermal conductivity, for absorption, for bremsstrahlung radiation, and for radiative recombination; a very useful collection.

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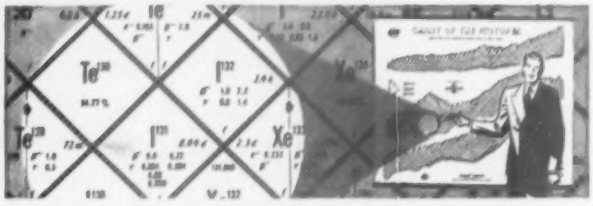

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You can tell at a glance based on the color code used, the type of nuclide, i.e., stable, naturally radioactive or artificially radioactive and the half live value ranges of the artificially radioactive nuclide.

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misprints, but on p. 88, line two, "small" is printed where "large" is meant.

In summary this book is both a readable account for one not familiar with the field and contains a useful collection of formulae for those already acquainted with the methods. One hopes that it will stimulate someone to write a larger book on this fascinating field.

Radiation Biology, Vol. 3—Visible and Near-Visible Light

Edited by ALEXANDER HOLLAENDER (McGraw-Hill Book Co., Inc., New York, 1956, viii + 765 pages, $10.00).

Reviewed by FRANKLIN HUTCHINSON, Biophysics Department, Yale University, New Haven, Conn.

This volume follows closely the pattern set by the first two volumes in "Radiation Biology" on ionizing radiation and ultraviolet light. Collectively the three volumes form a classic of that modern scientific publishing phenomenon, the "symposium" volume on recent developments in some active research field, with contributions from several authors.

This book contains fifteen contributions averaging about fifty pages each. They are:
Energy Exchange in Photoreactions (Lumry and Eyring); *Electronic Structure and Excitation of Polyenes and Porphyrins* (Platt); *Generation, Control, and Measurement of Visible and Near-Visible Radiant Energy* (Withrow and Withrow); *Energy Efficiency in Photosynthesis* (Daniels); *The Mechanism of Photosynthesis* (Wasink); *The Absorption, Action, and Fluorescence Spectra of Photosynthetic Pigments in Living Cells and in Solutions* (French and Young); *Chlorophyll Formation and Accumulation in Plants* (Smith and Young) *Nitrate Reduction* (Burstrom); *Phototropism* (Went); *Photoperiodism* (Borthwich, Hendricks, and Parker); *Seed Germination* (Evenari) *Viscosity, Permeability, and Protoplasmic Streaming* (Stalfelt); *Electrical Phenomena in Vision* (Riggs); *Invertebrate Photoreceptors* (Milne and M. Milne); and *Photodynamic Action and Its Pathological Effects* (Clare).

The book has taken an unduly long time to publish. Most of the manuscripts reached the editor some time in 1951, and essentially have not been altered since. In an addendum added to his contribution in proof E. C. Wassink says "Not withstanding the long time elapsed since this chapter was written, it still would seem to rep-

resent a fairly adequate general outline of the field." This reviewer feels that the comment is applicable to all of the articles. There are more recent reviews of some of the subjects treated, and some have been discussed in a more comprehensive and consecutive form, particularly the field of photosynthesis by Rabinowitch.

But the combination of most aspects of the biological effects of visible light into one volume, the competence of the authors, the comprehensiveness of the excellent bibliographies, and the convenience of articles of this length on a single topic, are all conclusive. This is a work that will remain a standard for many years, to be consulted often by anyone who has occasion to inquire as to the effects of visible light on living systems.

Nuclear Radiation Detectors

By J. SHARPE (Methuen & Co. Ltd., London, and John Wiley & Sons, Inc., New York, 1955, iv + 184 pages, $2.50).

This monograph (one of Methuen's series on physical subjects) gives an excellent, physical account of the properties of the devices used to detect nuclear radiation. There is little discussion of construction details and essentially none of electrical equipment. This is a good thing, for it permits concentration on the operation of the detectors themselves and quantitative discussion of all of the component processes. Often this takes the form of order-of-magnitude calculations that give a useful feeling for estimating detector behavior from first principles.

This emphasis on mechanism is also apparent in the general organization of the book. It treats first of the interaction of nuclear radiation with matter giving, for example, tables of the commonly used neutron-detecting reactions along with their cross sections and thresholds and the standard gamma-ray cross sections and heavy-particle range-energy data. The common detection media, both scintillating and ionizing, are then discussed quantitatively. The next chapter treats geometry and efficiency questions that are general to all counters as well as certain special cases. The remaining two long chapters are devoted to scintillation and ionization devices in more detail.

All in all this is a very useful little book with very high information density. American publishers would do well to present more of such special treatises.

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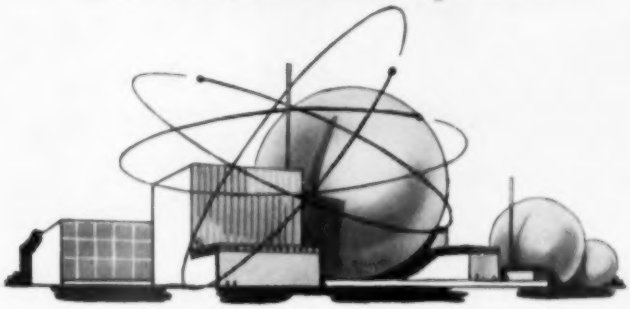

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BOOKS RECEIVED

Solid State Physics, Vol. 2, edited by Frederick Seitz and David Turnbull, (Academic Press, Inc., New York, 1956, xii + 468 pages, $10.00). (*To be reviewed.*)

Electromagnetically Enriched Isotopes and Mass Spectrometry, edited by M. L. Smith (Academic Press, Inc., New York, 1956, xvi + 272 pages, $8.00). (*To be reviewed.*)

Science and Information Theory, by Leon Brillouin (Academic Press, Inc., New York, 1956, xvii + 320 pages, $6.80). Initially a development of telecommunications, information theory has of late found use as a powerful scientific tool. In this very readable book, the author not only discusses the theory in its communications applications, but as a means of handling other physical information—thermodynamics, Maxwell's demon, general physics, the uncertainty principle. He goes on to consider printed information and computers.

Precision Electrical Measurements (Philosophical Library, Inc., New York, 1956, $12.00). This volume is the proceedings of an international symposium held in November '54 at the National Physical Laboratory, England. Twenty-six papers are presented in five sessions: "Capacitance and Dielectrics," Inductance and Magnetics," "Electrotechnics," "High-Voltage Measurements," and "High Voltage Impulse Testing Techniques." The discussions are included.

Synthetic Ion-Exchangers, by G. H. Osborn (The Macmillan Co., New York, 1956, ix + 194 pages, $6.00). The outstanding feature of this book is its 103-page bibliography. The author attempted to include in its two sections—applications and theory—all important papers. The rest of the book discusses the latest resins and techniques.

Molecular Flow of Gases, by G. N. Patterson (John Wiley and Sons, Inc., New York, and Chapman and Hall Ltd., London, 1956, x + 217 pages, $7.50). This analysis of gaseous flow considers those cases concerned with random molecular motion, rather than cases where flow can be treated as a continuum. An example of the former is the slip flow of a highly rarefied gas. Chapters cover isentropic and non-

isentropic flow and mechanics of rarefied gases.

The Production and Properties of Graphite for Reactors, by L. M. Currie, V. C. Hamister, and H. G. MacPherson (National Carbon Co., New York, 1956, 61 pages, complementary copies available to those in nuclear reactor work). This book is a complete printing of a paper presented at the Geneva conference, 1955. It discusses the electric-furnace production of artificial graphite and its properties.

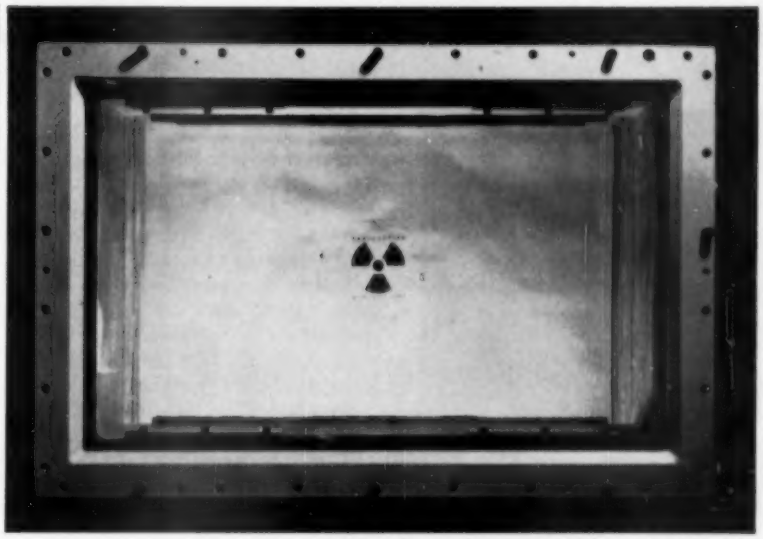
ALSO OF NOTE

Integral Functions. This monograph by M. L. Cartwright is No. 44 in the Cambridge Tracts in Mathematics and Mathematical Physics. It is mainly concerned with the theory of integral functions dealing with the behavior of a function of finite order in an angle—e.g., the Phragmén-Lindelöf principle and lines of Julia. *Cambridge University Press, 32 E. 57th St., New York 22, N. Y., $3.50.*

Mass Spectrometer Researches. In this 62-page pamphlet, published for the British Department of Scientific and Industrial Research, G. P. Barnard describes special features of an experimental sector-field mass spectrometer that was constructed at the National Physical Laboratory. Ion-source-design studies are also described, which were made to understand the role of the magnetic field in the source region. *Her Majesty's Stationery Office, York House, Kingsway, London w.c. 2, England, $0.63.*

Transistor List. Component data list No. 15T-756 provides a complete listing of commercial transistors of American and foreign manufacture, including major characteristics. All manufacturers of a particular type are given. A beta-to-alpha conversion chart and a formula conversion chart are included. *DATA, Inc., 67 Lawrence Ave., West Orange, N. J., $2.50.*

Plasticity and Water Retention of Hydrated Limes for Structural Purposes. By E. Levin, W. Clarke, and L. Wells, National Bureau of Standards Building Materials and Structures Report 146 reports an investigation of the plasticity and water retentivity of 65 structural hydrated limes from several production centers in widely separated sections of the country. *Government Printing Office, Washington 25, D. C., $0.15.*



Radiation Symbol photographed through a 36" thick piece of Corning Code 8362 radiation shielding glass is clearly visible.

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Are you planning a concrete cell? Corning Code 8362 nonbrowning lead glass will give you more shielding per dollar than any other glass.

A high quality 3.27 density glass, Code 8362 matches, inch-for-inch, dense concrete in shielding properties. And its high resistance to discoloration means good, long-term visibility not found in other types of "windows."

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Code 8362 has a refractive index of 1.594 and an internal transmittance of 93% in 5" thickness with sodium lighting. It's chemically stable, indifferent to moisture, and water-white. It cleans with soap and water, resists chipping and scratching.

It's cerium stabilized, resists browning and recovers rapidly from tinting. You can get it in single-piece thicknesses to 12" and sizes up to 100 x 70. We'll make the window you need to your specifications.

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1,600-hp unit is largest ever built. For Shippingport reactor, zero-leakage pump has been under test for a year. It will circulate 18,300 gpm of radioactive water through primary loop at about 2,000 psi and 590° F (see p. 76).—Westinghouse Electric Corp., Box 2278, Pittsburgh 30, Pa.

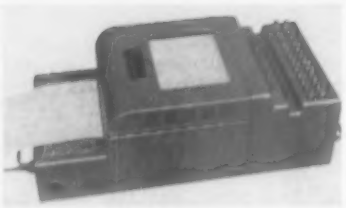
CONTROLLERS AND RECORDERS

Scanning Recorder

Particularly suited to thermocouple input, Type ND 51 can be used with any voltage sources. Records up to 54 variables and is especially useful in cases where all input values are normally constant and rapid appreciation of abnormal conditions is required.—Elliott Bros., Ltd., Nuclear Div., Lewisham, S. E. 13, England.

Recording Oscillograph

Eight-channel photographic recording system is designed primarily for recording analog computer output. Unit is 46 × 25 × 22 in. and provides push-pull or single-ended input into dual-channel d-c amplifiers. Sensitivity is 0.1 volts/cm. Input impedance is 5 megs. Frequency response is flat to 20 cps, down 2 db at 50 cps. Nine chart speeds.—Sanborn Co., 195 Massachusetts Ave., Cambridge 39, Mass.



Light-Beam Recorder

Model 420 offers 24-trace light-beam recording with automatic sensitizing, dry developing, and fixing. Unit features recordings to 100 cps, 7 paper speeds.—Century Electronic & Instruments, Inc., 1333 N. Utica, Tulsa, Okla.

Portable Controller

Model 6140 is miniature. Will control up to 500 watts of power. Has channel selection of four output functions. Can be used with photoelectric detector or proximity detector.—Autron Engineering, Inc., 1254 W. 6th St., Los Angeles 17, Cal.

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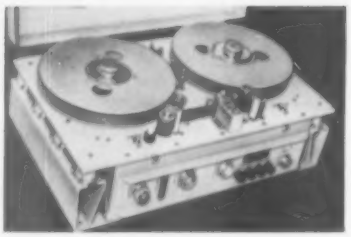
Graphic recorder. G-10 has 100-mv span, 2.5-sec balancing time. Optional models have 50-mv span and 10-mv span.—Varian Associates, 611 Hansen Way, Palo Alto, Cal.



Tape Transports

Model 541 (above) carries 2,400 ft of 1½-mil-base tape, 3,600 ft of 1-mil-base tape. Companion model 581 carries 1,200 ft of 1½ mil base tape. Recording and playback amplifiers are also available.—Davies Laboratories, Inc., 4705 Greensbury Rd., Riverdale, Md.

•

Miniaturized reactor-control instruments. A new line of miniaturized reactor control instruments, said to make no sacrifice in performance, are about $\frac{1}{20}$ the size, $\frac{1}{100}$ the weight of standard equipment. Transistorized scaler, weighing less than 2 lb, is capable of 60,000 cps.—Daystrom, Inc., 200 Elmora Ave., Elizabeth, N. J.

Nuclear magnetic resonance. Magnetic field control permitting accurate stabilization from 300 to 18,750 gauss, uses nuclear magnetic resonance.—Perkin-Elmer Corp., Norwalk, Conn.

CIRCUIT COMPONENTS

Plug-In Resistors

Plug-in fuse-type resistors for 5.6 ohms are said to withstand repeated high-surge currents but will fuse when surge becomes dangerous.—Clarostat Mfg. Co., Inc., Dover, N. H.

Products Index

Controllers and Recorders . 88
Circuit Components 88
Literature Available 90
Industry Notes 92

NUCLEAR NEWS FROM ATOMICS INTERNATIONAL

Industry's First Private Research Reactor Now in Operation

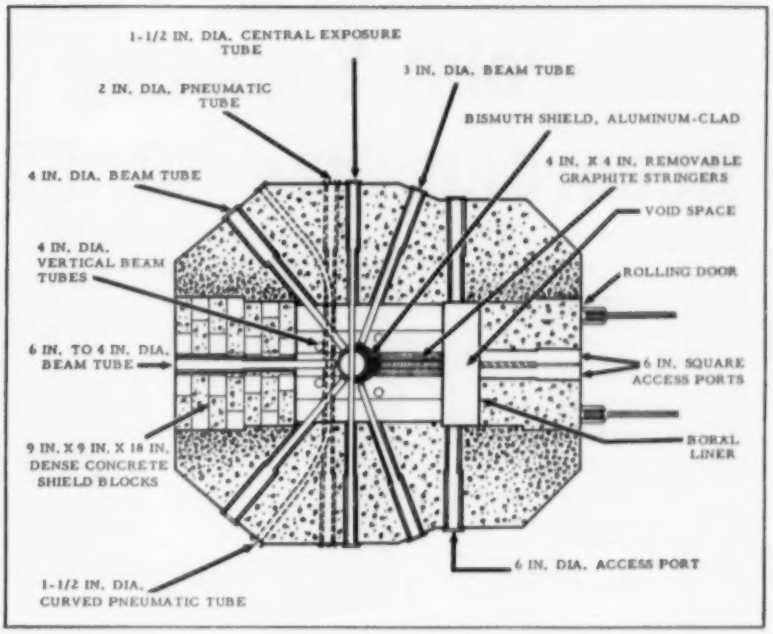
The Armour Research Foundation's nuclear reactor, located on the Illinois Institute of Technology Campus on State Street near Chicago's Loop, began operating early this spring. This marked the first time that private industry has had at its disposal a nuclear reactor expressly designed for industrial research.

Already under way at Armour are programs by participating companies, taking advantage of the revolutionary research techniques made possible by the new facility. The schedule includes allocation of reactor "time" for private studies, free of security restrictions. Areas of study include: food and drug processing; materials research – glass, ceramics, plastics, rubber, textiles, etc; petroleum, chemicals and other industrial materials and processes.

The Model L8 Armour reactor is of the homogeneous solution type, designed to operate at 50 KW and to produce a maximum thermal neutron flux of about 1.7×10^{12} neutrons/cm^2-sec at the center of the reactor core. Exposure facilities are provided through which the neutron flux is available in varying intensities for experimental purposes. Power level is controlled either manually or automatically by a vertical control-rod system. The reactor is safeguarded by a unique control system which "scrams," or automatically shuts down the reactor, if necessary.

One of several reactors produced by ATOMICS INTERNATIONAL, a Division of North American Aviation, Inc., the design and construction of the L8 Model is based on the company's 10 years' experience in the development of peaceful applications of nuclear energy. Other applications include a reactor designed for a prominent southern California university, specially adapted for cancer and other medical research; the important Sodium Reactor Experiment in the Santa Susana Mountains near Los Angeles, part of the AEC program to develop economical power from nuclear energy; plus development and design of a 75,000 KW sodium-graphite nuclear power plant.

ATOMICS INTERNATIONAL is a major reactor builder—experienced in the design, construction and operation of nuclear reactors for research and the production of power.


1-1/2 IN. DIA. CENTRAL EXPOSURE TUBE
3 IN. DIA. BEAM TUBE
2 IN. DIA. PNEUMATIC TUBE
BISMUTH SHIELD, ALUMINUM-CLAD
4 IN. X 4 IN. REMOVABLE GRAPHITE STRINGERS
4 IN. DIA. BEAM TUBE
VOID SPACE
4 IN. DIA. VERTICAL BEAM TUBES
ROLLING DOOR
6 IN. TO 4 IN. DIA. BEAM TUBE
6 IN. SQUARE ACCESS PORTS
BORAL LINER
9 IN. X 9 IN. X 18 IN. DENSE CONCRETE SHIELD BLOCKS
6 IN. DIA. ACCESS PORT
1-1/2 IN. DIA. CURVED PNEUMATIC TUBE

Reactor Plan View

ARMOUR RESEARCH REACTOR MODEL L8

Characteristics

Design Power	50 kw
Zero Power Critical Mass*	850 gm U^{235}
Maximum Thermal Neutron Flux	1.7×10^{12} n/cm^2-sec
Mass Coefficient of Reactivity*	0.03%/gm
Temperature Coefficient of Reactivity*	−0.029%/°C
Fuel Solution Temperature at 50 kw*	80° C
Excess Reactivity at 20° C, Zero Power*	3%
Reactivity Held in Control and Safety Rods*	8% (2% each rod)
H : U^{235} Atomic Ratio*	350
U^{235} Concentration*	75gm/liter
Power Density, Maximum	5.5 watt/cm^3
Power Density, Average	3.85 watt/cm^3

Approximate Value

Brief General Description—The reactor fuel is a light water solution of UO_2SO_4, enriched in U^{235}. This fuel is contained in a spherical stainless steel core tank, which is surrounded by a graphite reflector. The reactor is shielded with high density concrete (density 3.5 gm/cm^3) plus other selected materials. Fuel-handling, gas-handling and cooling systems are provided; also complete instrumentation and equipment are installed for remote operation and to provide automatic safety action.

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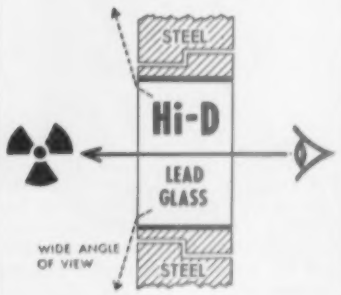

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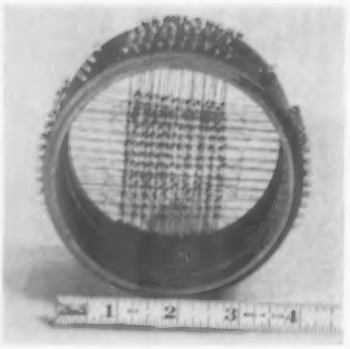


Magnetic-Bead Memories

Random-access memories with speeds up to 1μsec, come in units capable of storing 64 × 64 bits. Final soldering is done on the outside. Units can be stacked to form complete memory cylinders.—Transdyne Corp., 7337 Grand Ave., Maspeth, N. Y.

LITERATURE AVAILABLE

Automatic control. Cypak is an automatic control system with no moving parts, designed to replace relays. The four logic functions of Cypack systems, and the systems' design and application, are fully described in two bulletins: "Cypac Systems" (12 p.) and "The Whys and Wherefores of Cypack" (6 p.).—Westinghouse Electric Corp., 3 Gateway Center, Pittsburgh 30, Pa.

Radiochemical equipment. Glove boxes and laboratory hoods are described in several leaflets. Also available is "A Typical Radiochemical Laboratory," 8 p.—S. Blickman, Inc., Weehawken, N. J.

Axial-flow pump. Bulletin 1060, 4 p., describes ½ hp canned-motor pump designed for 20-ft head and 22 gpm.—Chempump Corp., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Shielding glass. Technical bulletin describes physical properties of three types of radiation-shielding window glass. 16 p., 10 graphs.—Corning Glass Works, Corning, N. Y.

Electronic instruments. 256-page catalog lists entire line of electronic equipment.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

Nuclear medicine. Medical radioisotope laboratory and anemia diagnosis with vitamin B_{12}-Co^{60} are the subjects of bulletins 77 and 75, respectively.—Tracerlab, Inc., 130 High St., Boston, Mass.

Mercury switch. Deltaswitch, using rotating mercury jets, is described in 2-page data sheet.—Norwood Controls, 934 Washington St., Norwood, Mass.

Memotron. New direct display storage CRT is described in 4-page brochure.—Hughes Products, Los Angeles 45, Calif.

Power equipment. Heat exchangers and feedwater heaters are described in two brochures. 2 p., 8 p.—Griscom-Russell Co., Massillon, Ohio.

Instrumentation. Brochure describes facilities and lines of electronic and nucleonic instruments.—El-Tronics, Inc., 1420 Walnut St., Philadelphia 2, Pa.

Well logging. Article in "Fansteel Metallurgy" describes use of neutrons and gamma rays in well logging.—Fansteel Metallurgical Corp., N. Chicago, Ill.

Hospital program. "Nuclear Medicine" is title of several brochures bound together. 51 p.—Abbott Laboratories, N. Chicago, Ill.

Thickness gages. Several 3-page leaflets describe thickness gages and associated equipment.—Ekco Electronics Ltd., Southend-on-Sea, Essex, England.

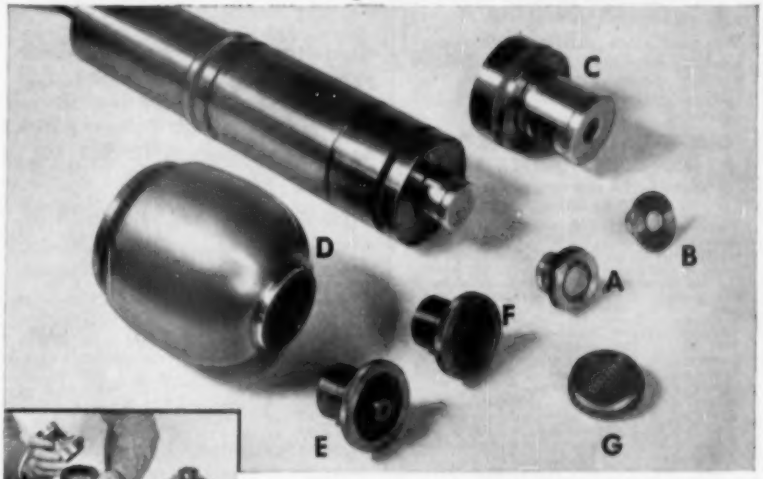
Well counter. Model CS-600 well scintillation counter and applications are described in technical bulletin.—NRD Instrument Co., 6425 Etzel Ave., St. Louis 14, Mo.

Research organization. Eight-page brochure describes new organization for research planning.—Quantum, Inc., 756 N. Brooksdale Rd., Fisher, Conn.

Scintillation detector. "Spectrogammeometer," consisting of scintillation counter and single-channel analyzer are described in recent issue of RCL counter.—Radiation Counter Laboratory, Inc., Nucleonics Park, Skokie, Ill.

TV camera. Brochure describes industrial television camera. 4 p.—Blonder-Tongue Laboratories, Inc., Westfield, N. J.

NEW! Multi-Purpose Scintillation Detector With Optional Accessories . . .



Optional accessories include (A) ¼", (B) ½", and (C) well scintillation crystals. Large lead collimator (D) provides exceptional side shielding, accepts 20° flat field collimator (E) or special focusing collimator (F). Alpha and beta phosphors (G) are interchangeable with standard 1" crystal.

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Crystal—Normally supplied with 1" x 1" NaI(T1) crystal. Other size crystals and phosphors optional. 1" x 1½" lucite light pipe. Crystal can be exposed directly in path of radiation.

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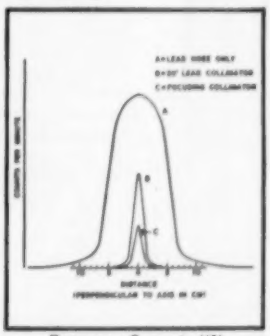
Operation (with 1" x 1" crystal)—Plateau: 250 volts; 2% slope/100 volts. Background: Crystal exposed—1250 cpm; with lead nose—160 cpm; with additional collimation—95 cpm. Detection efficiency (1 microcurie I^{131} at 10 cm): 4400 cpm.



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378 Bergen Blvd., Fairview, N. J.
Phone: Cliffside 6-0425

Instrumentation. Bulletin describes nuclear instrumentation, counter tubes, and voltage regulator tubes. 4 p.—Anton Electronics Laboratory, Inc., 1226 Flushing Ave., Brooklyn 37, N. Y.

Consultants. Brochure describes activities of organization dealing with reactors, shielding, isotopes. 4 p.—Advanced Scientific Technique Research Associates, P. O. Box 163, Milford, Conn.

Radiation protection. Bulletin N 20 describes film badge service.—Nucleonics Corp. of America, 196 Degraw St., Brooklyn 31, N. Y.

Radioactive chemicals. 32-page catalog lists radioactive chemicals and technical services.—Tracerlab, Inc., 130 High St., Boston 10, Mass.

Magnetic counter. Engineering bulletin 551 gives data on application of magnetic-shift register assembly in magnetic counters.—Sprague Electric Co., 259 Marshall St., North Adams, Mass.

Pumps. Bulletin 1050 describes line of canned-motor pumps. 4 p.—Chempump Corp., 1300 E. Mermaid Lane, Philadelphia 18, Pa.

Delay lines. Tapped and variable delay lines are described along with phasemeters, electronic counters in three bulletins.—Advanced Electronics Labs, Inc., 451 Highland Ave., Passaic, N. J.

Therapy sources. Recent issue of *Fansteel Metallurgy* discusses design of Co^{60} and Cs^{137} sources.—Fansteel Metallurgical Corp., N. Chicago, Ill.

Radiation Effects

This will be the subject of a comprehensive special report scheduled for the September NUCLEONICS. It will cover practical aspects of both the damaging and beneficial effects of radiation, including:

Status of understanding of mechanisms.

Where is radiation damage an important factor?

What is the status of data available?

How to interpret data.

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NEWSMAKERS

William P. Staker, formerly a senior physicist in the engineering research department of Standard Oil Co. of Indiana, has joined the staff of the reactor development division of Combustion Engineering Inc., at the new Windsor, Conn., laboratories.

Leonard W. Kates has been named manager of commercial development for the atomic energy division of Sylvania Electric Products Inc. He will be responsible for the division's metallurgical operations, for program planning, divisional planning in production areas, and industrial process engineering. With Sylvania since 1948, he was engineering manger in the atomic energy division.

Howard O. McMahon, science director of Arthur D. Little has been elected vice president of the industrial research firm.

Three new department chiefs and a new superintendent of manufacturing have been named at Atomics International division of North American Aviation. **F. E. Faris** will head reactor development, **E. E. Motta** will be chief of chemical process development, and **Alan Andrew** will be in charge of technical services. These three new departments, together with Research under **John P. Howe,** Engineering under **William E. Parkins,** and Component Development, to be headed by **Harry Pearlman,** constitute AI's technical operations, reporting to technical director **Sidney Siegel. D. N. Petersen** is the new superintendent of manufacturing, **R. L. Olson** takes over as chief of project engineering, and **A. B. Martin** has been named director of technical sales.

Atomic and molecular physicist **Harold J. Quinn** has joined the staff of the National Bureau of Standards, to do research and development on electron optical techniques for the study of gases at extremely low pressures.

C. Rogers McCullough, head of AEC's Advisory Committee on Reactor Safeguards, is the new president of the American Nuclear Society, succeeding **Walter H. Zinn. Jerome D. Luntz** was elected vice president for ANS' second year. Officers continuing are **Karl Cohen,** treasurer, **W. W. Grigorieff,** executive secretary, and **James G. Beckerley,** journal editor.

Air Marshal Sir Ralph Cochrane, former Vice-Chief of Air Staff in Britain and one of the men behind the Eder and Möhne "dam buster" raids in the last war, has joined Rolls-Royce Ltd. to take charge of the firm's nuclear research program. Since retirement in 1952 he has been managing director of a shipbuilding company. Sir Ralph will work at Derby where a new lab for research on nuclear marine and plane engines is being built by Rolls-Royce.

Westinghouse has appointed **O. C. Kebernick** administrative assistant to the manager of commercial atomic power activities, and **H. N. Muller, Jr.,** chief engineer of Canadian Westinghouse Co. Ltd.

James Van Horne Lawrence has been named director of engineering orientation at Ford Instrument Co.

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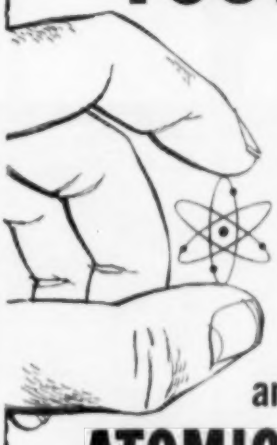

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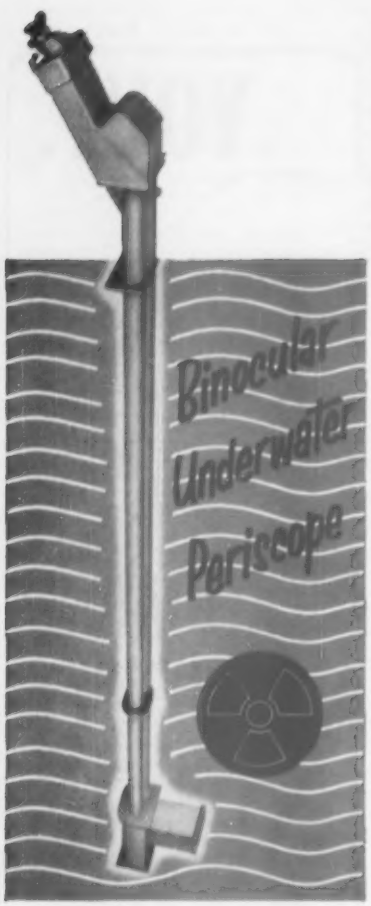

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A. M. Gurewitsch, physicist at General Electric's research laboratory, will be one of the lab's European scientific representatives, operating from the new GE research office in Zürich to cover new developments in physics. **George J. Szász,** named last fall as GE's first scientific representative abroad, covers chemistry.

Robert F. Mehl, director of Metals Research Laboratory and head of metallurgical engineering at Carnegie Tech, has been awarded the Grand Medal of LeChatelier by the council of the French Society of Metallurgy.

Cornell U. has appointed **Dale R. Corson** chairman of its physics department.

NUCLEAR CALENDAR

July 9–Aug. 10—Summer institute for college and university science teachers, sponsored by National Science Foundation at Oak Ridge Institute of Nuclear Science, Oak Ridge, Tenn. Contact ORINS.

July 22–28—Eighth International Congress of Radiology, Mexico City. Symposia on radiodiagnosis, radiotherapy, radiation physics, X-ray technology, radiobiology. Contact José Noriega, Box 21964, México 7, D. F.

Sept. 17–21—Eleventh annual international instrument-automation conference and exhibit (Instrument Society of America), New York (*Coliseum*). Contact Fred J. Tabery, 250 W. 57, NYC.

Sept. 25–27—Atomic Industrial Forum, annual meeting, Chicago (*Morrison*). Second annual Trade Fair of the atomic industry **Sept. 24–28,** Chicago Navy Pier. Contact D. J. Scherer, AIF (see above).

Oct. 8—Effects of Radiation in Metals, nuclear metallurgy symposium, at AIME Institute of Metals annual meeting, Cleveland (*Carter*). Contact AIME, 29 W 39, NYC 18.

Nov. 7–9—Ninth annual conference on electrical techniques in medicine and biology (AIEE, IRE, ISA) New York (*Governor Clinton Hotel*). Will include field trips to installations of interest. Contact E. Dale Trout, General Electric Co., X-Ray Dept., Milwaukee 1, Wis.

Nov. 22–23—Symposium on Calder Hall nuclear power plant (British Nuclear Energy Conference), London. Contact A. McDonald, Sec'y, Inst. of Civil Engineers, 1-7 Great George St., London S.W.1.

Nov. 25–30—Annual meeting ASME, New York (*Statler*). Three technical sessions will be devoted to nuclear engineering. Contact B. R. Prentice, ASME, 29 W 39, NYC 18.

Nov. 26–30—Twenty-second National Power Show (ASME), New York (*Coliseum*). Will include enlarged nuclear power display section. Contact ASME, 29 W 39, NYC 18.

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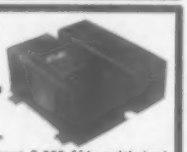

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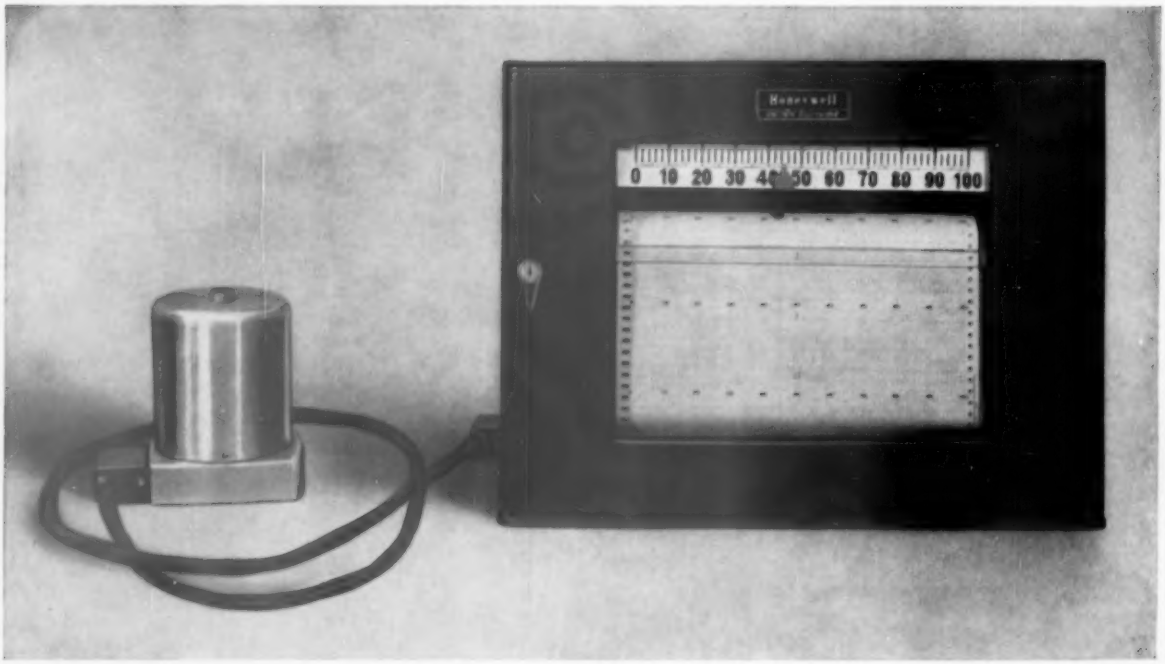

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